The Solar System

OUR NEW FRONT YARD

Clifford Simak

IN RECENT years science fiction fantasies of man's first encounter with unknown worlds have suddenly approached the brink of reality. Astronauts have already orbited the Earth and space is rapidly becoming overcrowded with the satellites and rockets man has put there. Now that Project Apollo is under way it cannot be long before there will be a man on the Moon. His curiosity is unlikely to be satisfied with that alone. The Moon will be an excellent jumping-off point for excursions even further into space. Sooner or later, Mars, and maybe even Mercury and Venus, will be on our space shipping route.

The Solar System is the ideal book for young readers who want the facts—as far as they are known—behind the fiction. Mr. Simak is a successful scientific journalist who writes easily and entertainingly and wears his learning lightly. He starts by discussing at some length the stumbling blocks which still prevent us from reaching the Moon; for example the radiation belt surrounding the Earth, the stresses resulting from the enormous acceleration needed to get clear of its gravitational pull, the attendant problem of weightlessness when this has been achieved, the survival of the intense cold and lack of atmosphere once on the Moon. But none of them is insuperable. He then describes the solar system which will be seen so much more

(Continued on back flap)

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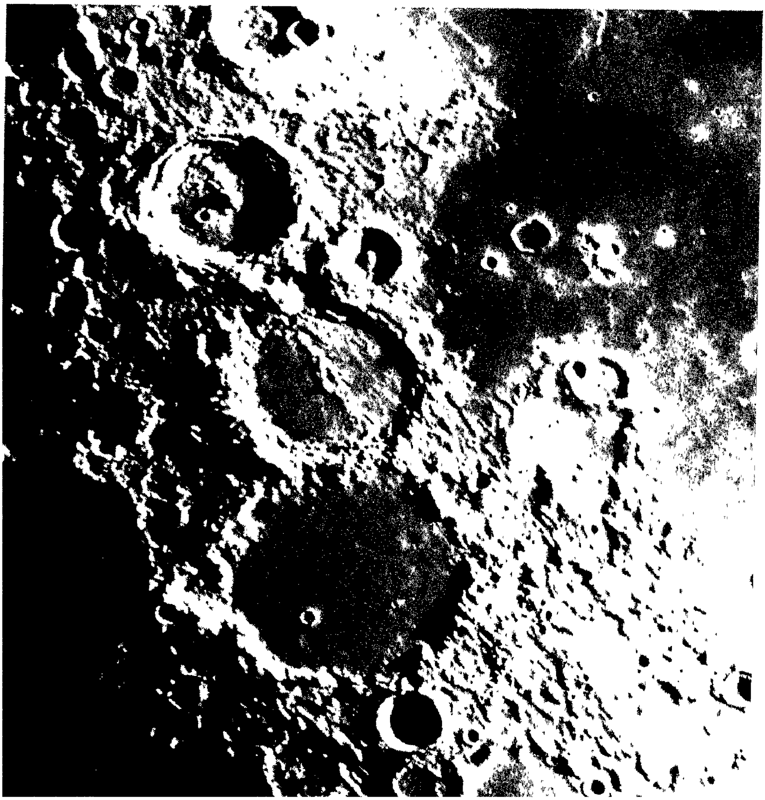
Clifford D. Simak



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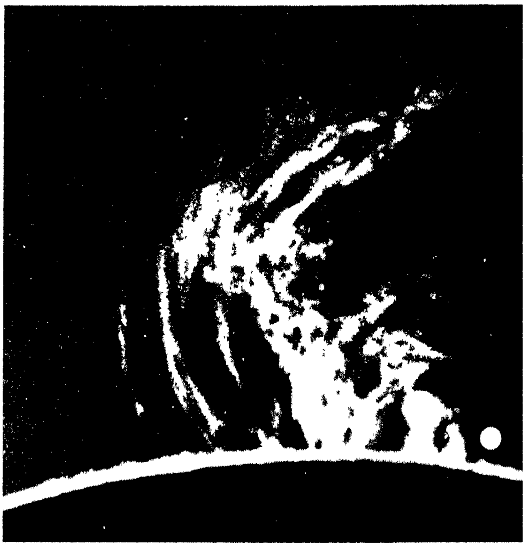

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1.

The Radiation Barrier

TODAY MAN STANDS ON THE BRINK OF HIS GREATEST adventure. Within a few more years he will be going into space—out to the Moon and the nearby planets in the solar system.

The machines which will take him there are now being built. Man himself already has gone a short distance into space; his rocket probes, carrying instruments, have gone a good deal farther—millions of miles from Earth.

The first man to go into space was Major Yuri Gagarin, an officer of the Russian Air Force. On April 12, 1961, he circled the Earth at a height of 200 miles, encased in a capsule which was the forerunner of the spaceship. Since then others have followed him; and there will be more and more. But such low-level flight is only the first step into space. It is really little more than practice, a trying out of machines and men, paving the way for that day when spaceships will span the distances between the Earth and our neighboring planets.

Man must creep carefully into space, feeling his way

as he goes. There are things he does not know as yet, things he will have to learn before he heads for the Moon.

Unmanned machines have gone ahead of him, nosing out beyond the Earth, discovering some of the things which man must know, and radioing back the word.

A Russian rocket has hit the Moon. It may lie there today at the bottom of the pit it dug. Another rocket, also Russian, has circled the Moon and taken pictures of its hidden side.

An American rocket, traveling inward toward the Sun, sent back messages to Earth until it was more than 22 million miles out in space. Then its radio signals failed; but the rocket itself, the so-called Venus probe, went on. Today it is still out there somewhere, traveling the great orbit into which it was shot. It is called the Venus probe not because it was aimed at the planet Venus, but because it was sent into a path which took it inside the orbit which Venus makes about the Sun.

Just this last year the Russians aimed a rocket toward Venus. But the radios in the Russian rocket failed when it was only a few million miles from Earth. The Russian rocket also is out there now, following a path similar to the one traced out by the American Venus probe.

In addition to these far travelers, two other rockets are describing a long circle around the Sun. Fired past the Moon, they escaped Earth's gravity and became man-made planets. One of them is Russian, the other American.

These are the rockets which have gone far out in space. But there are many other rockets which have been fired into orbits to circle the Earth. These rockets are called satellites. They carry many types of instruments to gather information which is radioed back to us.

Since the first satellite was sent up to spin about the Earth, on October 4, 1957, more than fifty satellites in all

have been put in orbit. Roughly half of them are still up there.

The first satellite, Sputnik I, was launched by the Russians. So was the second. The Russian satellite shots have been more spectacular than the American shots. The Russians have been able to put up heavier rockets. They put the first man into space. But, all in all, far more American rockets have been put into orbit around the Earth. They have stayed up longer and have performed better in obtaining information than have the Russian rockets.

If this book were one concerned with international relations, there would be much more that would have to be said about the space race between America and Russia. But this is a book about the solar system and what man will find there when he ventures into it. Here we must take a longer view.

A hundred years from now it may not be as important as it seems today that an American or a Russian accomplished something first. What will be important then, and vitally important, is that in the fifties and the sixties of the twentieth century man set his feet on the pathway that would take him beyond the planet of his birth.

What has been done in space so far should be viewed as an accomplishment of the human race, not of any nation. And it well may be that our very accomplishments, in the end, will serve to weld together the interests of all humanity so that there will be less hatred in the world.

Man always has been an adventurer. He always has wanted to see what lay around the next bend in the river. He has always climbed that one last hill to see what lay on the other side.

His urge for adventure led him to explore the Earth. It was a desire to see "what lies beyond" that drove Columbus across the Atlantic to discover America. It was a

hankering to see that sent men, at great danger and in discomfort, into all the far corners of the world.

Today there are few geographical frontiers left on Earth. We still have to explore the ocean depths. There still may be some land in the Amazon jungle where no man has as yet set foot. But, by and large, the earthly frontiers have vanished.

But now we have a new frontier of space, a greater frontier than we can imagine—a frontier that goes on and on as far as man may want to wander.

For years man has dreamed of going into space. Today the way to space is open. The engines have been tested and we know how to go. The only thing not yet fully tested is the man who will ride those engines.

The only thing which can now stop man from going into space is man himself.

In those old days, when we only dreamed of going into space, the whole thing seemed simple—if we could only get the machine that would take us there.

Today the prospect of conquering space is no longer simple. Now we have the machines, but the problem itself has become complex. There is more to going into space than just solving the problem of how to get ourselves out there.

Once we thought that space was empty. We stood outside at night and looked up at the sky, and it was empty. You could see that it was empty. You could sense the emptiness. On a quiet, clear night you could almost hear the emptiness. There was nothing there to stop you if you could just get going.

A meteorite, perhaps, might come zinging out of nowhere and drill a neat hole in your ship—which you could patch, of course. Or a bigger one might smash the ship beyond possible repair and that would be tough luck. But there were, the scientists told us, not as many meteorites per

cubic mile as we might think; the chance of a ship's being damaged by one was really quite remote.

Or there was a chance that the heat of the sun might warm up the metal of our spaceship so we'd hang out there and broil. But we had ways of licking that. We could rotate our ship, so that no one side of it would ever be exposed to the Sun long enough to build up any heat. Or we'd build it of material that would not absorb the heat. Or we'd have some sort of effective insulation. Or we might devise a reflector shield. There were, we said, a lot of ways to lick it.

But aside from these two matters—the heat of the Sun and the meteorites—we had hardly any worries.

But now that we have sent machines into space to gather data for us, we find there is more out there than heat and meteorites.

We have a worry now—a big one. It is radiation.

To understand what radiation is, we have to back up for a minute and do some studying.

Almost everything that exists is composed of atoms. We have to qualify the statement, and say "almost everything," instead of everything, because light and other electromagnetic radiations are not composed of atoms. A radio wave is another example of electromagnetic radiation.

But everything we think of as matter, even human beings, is composed of atoms. An atom, in turn, is composed of several things.

The simplest atom is the hydrogen atom. It is made up of one proton, which is the atom's nucleus, and one electron, which spins about the proton. The proton has a positive electrical charge. The electron has a negative electrical charge. The two charges cancel one another out, so that the hydrogen atom is not charged electrically. This is true of all other normal atoms.

An atom is a small thing. To get an idea of its size,

remember that there are about 600 sextillion atoms in a gram of hydrogen. Six hundred sextillion is 600 followed by 21 zeros. It takes not quite thirty grams to make an ounce of weight.

Another way to say it: An atom bears about the same relationship to the period at the end of this sentence as the period does to the size of Earth.

And if you think that is small, consider the electron, which is a part of the atom. The proton which makes up the nucleus of the atom has a mass 1,836 times greater than that of the electron.

Perhaps this is as good a place as any to explain "mass"; it is a term we'll be using all through this book. On the Earth we think of a thing's weight, whether it be a grain of sand or an elephant. Weight is a value we arrive at when we consider the result of gravity upon something. We say a thing weighs so much, which is in reality the measure of how much it is pulled down or held down by gravity. But far out in space, and under certain other conditions, the same object would have little or no weight, because there would be no gravity, or no great amount of gravity. And on some other planet, where the gravity was greater than it is on Earth, the object would weigh more than it does on Earth. But whether it weighed twice as much or nothing at all, it still would be as big as ever and would contain as much matter as ever. Under conditions where there is no gravitational effect, we cannot say it "weighs" so much, because actually it weighs nothing. But we have to express its size and its amount of matter somehow; so we say it has so much mass.

To get back to the atom: Since a proton has a positive charge, to form a stable atom it must be balanced by the negative charge of an electron. Thus any normal atom has

an equal number of electrons and protons. It is the number of protons in the nucleus that determines the identity of an atom. An atom with only one proton always is hydrogen; with two, it's helium; with three, lithium; and with fifty, it is tin.

But within the nucleus of all atoms, with the one exception of hydrogen, we find another particle—the neutron. The neutron has a mass of 1,839 (that is, it is 1,839 times more massive than an electron) and has no electrical charge. While a normal atom must have equal numbers of electrons and protons, this rule does not hold true with neutrons. Since neutrons have no electrical charge, they need not be balanced off. The number of neutrons within the nucleus will affect the mass of an atom, but not its electrical charge or its basic identity.

This situation explains what we call isotopes.

An atom of tin, with fifty protons, always will be an atom of tin, but there are ten isotopes of tin—that is, ten types of tin, each differing slightly from all the others. This difference is due to the difference in the nuclear mass occasioned by the number of neutrons in the nucleus. There can be as many as 74, or as few as 62.

Each of these basic atomic patterns forms an element. Hydrogen is an element, so is tin. The ten different forms of tin make no distinction so far as the element itself is concerned; they are simply isotopes of tin.

Until a few years ago there were only 92 known elements. Since then ten others have been made in laboratories. With the exception of plutonium, which does occur naturally in small amounts, none of the other nine is thought to occur naturally. They are strictly man-made. If they ever occur on Earth at all it is for so brief a period that they scarcely count.

It is frequently said that the atom is a sort of miniature solar system, with the electrons orbiting about the nucleus as the planets orbit around the Sun.

If you prefer, it does no great harm to think of it in that way. Actually, however, the electron does not have any definite orbit. The so-called orbits simply are regions in which there is a good chance that an electron may be found. An electron, under certain conditions, is apt to jump around a lot.

Which brings us to radiation.

Normally, an electron will move in the innermost of its several possible orbits. But when something occurs which causes the electron to absorb energy, it speeds up and climbs up into an orbit farther out from the nucleus. When the electron drops back to its normal orbit, it gives up its extra energy in a burst, giving rise to what we call a quantum (that is, a bundle) of radiation. Under some conditions, the radiation given off may be light. Under other conditions, it may be a gamma ray, which is the same thing as an X-ray. Or it may be an ultra-violet ray, which is the ray that gives you that bad case of sunburn every spring. Or it may be heat. In all cases, it is what we call electromagnetic radiation. There are no actual particles involved.

But in some instances, the amount of energy which is absorbed by the electron is much greater. Instead of just climbing into a higher orbit, the electron is knocked entirely out of its orbit, so that it becomes a free electron: that is, an electron not a part of an atom.

When this happens we have what is known as ionizing radiation—which is the kind we are principally concerned with in our effort to go into space.

In its normal, balanced state, an atom has no electrical charge. But when an electron is knocked out of orbit, we have a negatively charged free electron and an unstable (be-

cause it has been unbalanced by the loss of an electron) and positively charged atom.

Man deliberately produces ionized radiation in his laboratories for research work. He produces gamma rays in his X-ray machines. But in research, the radiation is kept under control and safeguards are set up against it.

For radiation can be deadly dangerous.

Because of its great energy, radiation is able to penetrate matter. As it penetrates matter, it gives up some of its energy to atoms which are adjacent to its path. These atoms then become excited because of the extra energy. In some cases the atoms are broken up and become ionized in turn. A living thing, exposed to too much radiation, will become ill because of tissue damage—damage done to the atoms of the body by the radiation. Too great a dose of radiation can kill.

Out in the center of the solar system we have a great radiation factory—the Sun.

It pours out heat and light, ultra-violet rays, some gamma rays, even a few cosmic rays, and a host of ionized particles which spread out into space for millions of miles. In fact, the Earth actually lies within the outer reaches of the Sun's atmosphere. It is a very thin atmosphere by the time it reaches out to Earth, but still filled with all the by-products of the Sun's continuing operation.

Our own atmosphere shields us from the most harmful of these radiations. Were this not so, life would be impossible on Earth.

But up above the Earth's atmosphere is another mechanism which also helps to shield us from the radiations. It is called the Van Allen radiation belt, named after its discoverer, Dr. James A. Van Allen of Iowa State University.

To understand this belt, we must remind ourselves that the Earth, among many other things, is a huge magnet.

If you take a magnet and place it on the table, and then sprinkle iron filings around it, the filings will arrange themselves along definite lines. These lines are shaped somewhat like wings on either side of the magnet, with the lines pinching in at each end of the magnet, but flaring out on each side.

What has happened is that the iron filings have lined up with the magnetic lines of force which surround the magnet. The area about the magnet is known as the magnetic field.

Since the Earth is a magnet, it also has a magnetic field; and within this field are magnetic lines of force.

As ionized particles from the Sun come streaming in toward the Earth, the Earth's magnetic field traps them just as the magnet on the table traps the iron filings.

But with one difference. The iron filings fall into place and stay there. The particles trapped in Earth's magnetic field are still charged with excessive energy. So they go whizzing round and round, following the lines of force. It is this trapped assemblage of particles which form the Van Allen radiation belt.

At the time the belt was discovered by Van Allen, it was believed to be two, possibly three, belts, with the space between each of them relatively clear of radiation. But recent data collected by the satellite, Explorer XII, show that it is only one belt, of much greater extent than first believed.

Beginning at the height of about 600 miles above the surface of the Earth, it extends out to 30,000 or 40,000 miles. Scientists are now beginning to call this area of radiation the magnetosphere. It probably should be considered actually as a part of the Earth's atmosphere.

While most of the radiation which it contains must be fed into it by the Sun, it is likely that cosmic rays may account for some of the radiation at its lower edge.

Cosmic rays are particles which come zooming out of

space at tremendous speeds. Most of them apparently come from the distant reaches of our own galaxy; but there may be some that come from other galaxies. They are moving at a speed close to that of light, which is 186,000 miles per second. This, incidentally, is as fast as anything can travel. Some cosmic rays, traveling at a slower rate, come from our Sun.

As the cosmic rays race into the atmosphere, they collide with the atoms and molecules which make up the atmosphere. The collision causes the atoms and molecules to break up; but in the process, the cosmic rays lose all their energy and cease to exist. Some of the debris caused by the collisions eventually reaches the surface of the Earth and is known as secondary radiation. But part of it bounces back into space and is snatched up by the Van Allen belt.

The Van Allen belt encloses the entire Earth—except the regions over the North and South Poles, because the lines of force pinch in at the poles. The belt resembles a huge doughnut, with the area over the poles the hole in the doughnut.

So there you have the picture—the Earth virtually surrounded by an area which is a raging sea of radiation.

To get into outer space, man either will have to run through the belt, or duck it (and there is a way to duck it). No one as yet knows how dangerous it is. It may not be as bad as we think. It could be a good deal worse. It could, just possibly, be certain death to any life that ventured into it.

No man as yet has come close to it. The astronauts, as they circled the Earth at an altitude of 200 miles, were still a good 400 miles beneath the edge of the belt.

The instruments which we have sent up in our satellites to measure the radiation in the belt tell us it is vicious.

Dr. Van Allen, who discovered the belt when he sent up a radiation counter in one of our first satellites, suggests

that if we could run through the belt fast enough we might not be hurt too badly. He compares it to running barefoot over a bed of red-hot coals: If you run fast enough, you won't get more than singed. The length of time you stay exposed to radiation has as much to do with how badly you are hurt as does the intensity of the radiation.

But even to run through the belt quickly, you still would have to have more protection than the metal walls of a spaceship afford. There would have to be a special shielding to stop some of the radiation.

The shielding probably would be made of lead. But lead adds weight, and the more weight there is, the harder it is going to be to boost a spaceship off the Earth.

If a quarter-inch of lead shielding were used, the extra weight for a one-man spaceship would come to a ton. A ton is a lot of extra weight. It would take more tons of extra fuel to shoot the ship into space and out toward the Moon.

By using shielding, by choosing the shortest route through the belt, and by piling on as much early speed as possible, we might have a chance of getting a man through the belt without his being hurt too badly.

There is a way, if the belt proves too dangerous, for us to dodge it altogether: We could shoot our ship into space over the poles—out through the hole in the doughnut.

There are two objections to this.

If we shoot our ship toward the east, either on the Equator or close to the Equator, we have the rate of Earth's rotation as an additional factor in giving the ship some speed—and thus a better chance of getting quickly into space. If we shoot it "across the grain" of the rotation—which would be the case in shooting it out over the poles—we lose that advantage.

The second disadvantage of dodging the belt is that by shooting a ship into space over the poles, we would be plac-

ing it in an awkward position for aiming at the Moon, which certainly will be our first objective.

As a matter of fact, however, the Van Allen belt, while it may cause us some inconvenience, will not stop us from going into space. We will either go through it fast, or, if we can't do that, we'll dodge it.

But there is something else that, while it may not actually stop us from going into space, may make the venture extremely dangerous.

The Sun, as we have seen, pours a flood of radiation out into the space around it. In 1959, the most deadly kind of this radiation was discovered at the University of Minnesota by Drs. Edward P. Ney, John R. Winckler, and Phyllis Freier.

The three scientists found that storms of radiation originating within a solar flare are composed of protons. Protons are relatively heavy—that is, they have more mass than electrons. For this reason, they are harder to stop, and can do more harm to living tissue.

A solar flare is a sudden brightening of an area of the Sun, almost as if a blinding explosion had taken place just beneath the surface.

Not every flare produces a proton storm; but many of them do. There is as yet no way of knowing which flares will produce a storm and which will fail to do so.

As a proton storm sweeps toward the Earth, the protons follow the lines of force in Earth's magnetic field down to the polar regions, and come plunging into the atmosphere. Few of them reach the ground, because they collide with atoms and molecules in the air and lose their energy. But during the time that a storm is in progress, they are funneled in a raging torrent down through the holes in Van Allen's "doughnut."

Any ship which happened to be out in space at the time

of such a proton storm would catch the full brunt of it. The protons are hurled far out in space, probably as far as the orbit of Mars.

The thing to be borne in mind is that proton storms are more deadly than anything to be found in the Van Allen belt. So we would need the shielding we have been talking about not only to get us through the belt, but to guard us against bursts of radiation, such as the proton storms, once we go into space.

A ship going out through the "hole in the doughnut" in an effort to duck the belt would be unlikely to run headlong into a proton storm; for it takes some time for a storm to reach the Earth after it has been hurled out by the Sun. Flares on the Sun are unpredictable and can occur with no advance warning. But once a flare was spotted on the Sun (and the Sun is under almost constant observation) warnings would go out to stop any spaceship that might be heading out over the polar regions.

It may be that in years to come—maybe any day now—someone studying the Sun will get a clue which will allow us to predict not only when a flare will occur, but also under what conditions a flare will produce a proton storm.

Outer space is filled with radiation, but apparently nothing, other than the Van Allen belt and the proton storms, that we need to fear too greatly.

These two types of radiation present a considerable problem. The brute force method of using shielding to protect ourselves is an unsatisfactory way of solving the problem. Probably there are better ways, although none has been developed so far.

We may run into other problems just as bad or worse once we get into space. But as of now the one big question is the radiation problem. The question is: Can man live in

space? Is he tough enough to take it? Can he figure out a way to protect himself?

Centuries of history have taught us one thing: When man is faced by a problem, he usually finds a way of solving it. It may take a while; but the chances are good that man can solve the problem of radiation, too.

2.

Some Space Flight Problems

WITHIN THE NEXT FEW YEARS MAN WILL TRY TO reach the Moon. The chances are he'll make it. Apparently radiation is the only thing that now stands in the way; and we can have some confidence that it can be overcome.

But the question arises: Why should we want to conquer space? The answer to that one is liable to be very complicated.

There are many good, sound reasons why we shouldn't even try. There are few which support our going.

Going into space is going to be a costly business. Already we have spent a vast amount in research, in preparation and in training, in building rockets—and then in building others because the ones we made last year already are outdated.

We often hear what sound like two perfectly logical reasons for going to the other planets. One of them is that

we may find new resources there. The other is that the planets may represent future living space for a world that is beginning to become just a little crowded.

But neither of these arguments stand up.

Even if we found coal, oil, iron or other minerals on the other planets, the cost of shipping them back to Earth would be prohibitive.

And the planets, as they now stand, represent no living space at all. Life would be possible on both the Moon and Mars, but only if we lived in structures which would shield us against the harsh conditions we will find there. The structures would have to be stocked with food and air and water, plus all the other necessities of life. Every bit of this would have to be hauled from Earth. In other words, we would be living in what amounted to a grounded spaceship.

Venus probably is unfit for human habitation. Mercury is too hot. Jupiter and the other big planets are the wrong kinds of worlds entirely. Pluto is so far out, so cold, so lone, that it would be surprising if man could survive there without the most elaborate safeguards.

So, if anyone should want to argue against exploring the solar system, he would have some telling points: The program is going to be terribly costly, and there is nothing out there that we really want or need.

But the answer to the last part of that argument is that we don't know what we'll find. While we have no guarantee that we'll find anything of value, there always is a chance that something of outstanding value might be found. Something, perhaps, that we don't even dream of now. Something that even in our wildest imagining we have never thought of.

It's a sort of grab-bag proposition. You won't know what you're going to find until you get there. Our total sense of value is limited to our earthly sense of value. We think of iron and oil and diamonds. We may find none of these; but

we may find something that we have no name for now, that we never knew we needed until we held it in our hand.

The one thing we'll certainly find is knowledge—and knowledge of many different kinds. No one can put a dollars-and-cents value on knowledge. And yet there is no doubt that it has a monetary as well as an intellectual value. All the progress we have made in all our history has come about as the result of knowledge of one sort or another. Anything—anything at all—which adds to the sum of human knowledge is worth the effort.

But once again, we can't be certain of exactly what kinds of knowledge we will find.

Scientists will tell you that once they get to the Moon they are hopeful they will find the answers to some questions they have been asking about the Earth. The Moon has been an unchanging place for millions of years. It and the Earth must have come into being at about the same time. The scientists hope that the unchanging Moon may have preserved certain formations which years of weather and erosion have wiped off the Earth.

Too, we may find on the other planets some evidence as to how life could have come about. It is possible that on the Moon we may find the so-called pre-life molecules which just possibly may have given rise to life on Earth.

Life is the one thing above all others that man hopes to find elsewhere in the solar system. It may be that man feels lonely at the prospect that ours is the only planet on which there is any life. Or our desire to find other life may be no more than neighborly curiosity about the house next door and whether or not there are people living in it.

There is a fairly good chance that we'll find life on Mars. The other planets are poor bets for life. So are the moons which circle the other planets. So is our own Moon.

Astronomers would like to set up an observatory on the

Moon. With no air to distort the vision, with no clouds to blot out the sky, with the seeing almost as good during the lunar day as it is at night, a telescope on the Moon undoubtedly would unlock many of the secrets of the universe.

So it finally stands this way: We may not find on the other planets a single thing we can convert into actual money. We are almost certain to find knowledge which in time will give us a monetary return. We are not at all certain of what kinds of knowledge we will run across; but we have, to start with, some definite ideas of what we'd like to look for.

However, we'll not be going to the other planets for the sake of knowledge alone. We'll be going because space has now become the next bend down the river, because it is that last hill just ahead.

In going into space, man will be driven by the same motive which has driven him since the first faint dawn of reason—the impelling urge to go and see what no one else has seen.

Man will face death and danger in the doing of it. He'll be going into a medium which he has never faced before. He'll have to provide his own defenses against that medium —against emptiness and cold and heat, against radiation and the loneliness, against the mind-racking thought that when he reaches journey's end he'll be farther from his kind than man has ever been before.

And he'll have to carry within the spaceship everything that he needs to keep himself alive.

When Columbus headed his ships across the then unknown Atlantic, he still had air to breathe. He still had fish to catch. He still was on an old and familiar planet. At any time he wished, he could have turned around and gone back home again. When a wagon train, years later, pushed into the relatively unknown west, the people with the train knew that they would find food and water along the way. They knew

there were places where they could stop and rest and refresh themselves for the next big pull ahead. And they, too, could turn around and go back if the way ever got too hard.

But in space there'll be nothing along the way. If you run out of water, that is the end of it. If you run out of air, there is no place to get more air. No matter how much you may want to turn back, there is no turning back.

Going to the other planets will be the sort of adventure that will take the best that man has in him. It is a challenge—and the exact sort of challenge that man through the ages has been unable to turn his back upon. It will cost a lot of money and it will cost some lives. It will take a lot of planning.

Some of that planning is being done right now.

Part of it has to do with ideas on how we may beat radiation.

One suggestion is that a spaceman, while going through the Van Allen belt or other areas of radiation, may offer less of a target and suffer less damage if he comes as close as possible to rolling himself into a ball. He would pull his knees up against his chest, wrap his arms around his knees, bend his head down to the knees. Not only would this position offer a smaller target for the radiation, but it would offer some protection to the organs in the chest and abdominal cavity.

The position is not too uncomfortable and in going through the Van Allen belt, at least, it would not have to be held too long—perhaps not longer than an hour.

Another idea is that special body armor might be used. This armor would be of lead and would be in addition to the shielding on the ship. It would be uncomfortable to wear and it would add some extra weight. But it would need to be worn only when the ship was passing through an area of high radiation.

Another possibility is the submersion of the body in

water. Water is fairly effective at stopping radiation. And it would have another value. It would serve as a cushion at the beginning of the trip against the stress of increased gravity.

Two other suggestions which might prove helpful against radiation are the use of drugs and the lowering of the body's metabolism.

Work in laboratories has shown that the use of certain drugs will reduce radiation damage to living tissue. But the drugs must be taken before the person is exposed to the radiation; they are a safeguard, not a cure. And, so far, they give protection for only a short time.

But there is a drawback. To date the only drugs found useful have proved harmful to the human body if taken in large enough quantities to afford any appreciable protection against radiation. It is hoped that further research can eliminate this toxic quality, at least in part.

Decreasing the body's metabolism involves lowering the body's temperature and slowing the bodily functions.

Experiments in radiation during lowered metabolism have been tried on hibernating animals. The animals suffer no signs of radiation damage during the time they remain in hibernation. Time seems to have no bearing on the matter; the animals may sleep for weeks after being exposed to radiation and show no signs of it. But upon awakening, the first symptoms quickly appear, and the animal suffers the full effects of radiation poisoning.

This, of course, provides no answer; but it is a lead. Further research is continuing in the hope that something may be found, some hint, some clue, that will lead to some sort of answer to our problem.

There is one catch, of course: Human beings do not hibernate. So if hibernation should prove to be the answer to the radiation problem, we then would have to find some method of slowing up the functioning of the human body for

long periods of time. Freezing the body, to the point where the bodily functions would be slowed and yet not so far that life would be endangered, is one way that suggests itself. There is little question that such a thing would be feasible; but at the moment the proper technique has not been developed.

The problem of protecting humans from the radiation which will be found in space is a relatively new one. There has been only a short while in which to work upon it. It is not too much to hope that in time—perhaps in the next few years—the problem may be solved.

Another situation which at one time caused more worry than it does now is the so-called g-tolerance of the human body. G in this instance means gravity. Earth's normal gravity is designated as one g. Twice Earth's gravity would be two g.

On liftoff, when the spaceship is building up speed to escape Earth's gravity, a man riding in a spaceship would be subjected to several times Earth's normal gravity. Present figures seem to show that a man would not experience much more than about 10 g in a spaceship takeoff.

Ten g, however, could kill a man unless special precautions were taken. By the use of acceleration couches, harnesses to support the body, and perhaps even immersion in water, as mentioned earlier, the body could be cushioned to absorb the stress of added gravity.

It would appear, however, that this problem has been largely solved. Both Russian and American astronauts experienced more than 10 g in their flights into space and, protected by acceleration equipment, felt no ill effects. With elaborate safeguards, Col. John Paul Stapp withstood as high as 40 g when he rode his rocket sled. This stress lasted, however, for only a few seconds. No one, even with the best protection, could exist under 40 g for long. Stapp said the experience was like "riding on the nose of a 45-calibre bullet."

Gravity increases not only with rapid acceleration, but also with rapid deceleration. A fast stop is just as bad as a fast start.

We have been talking here about gravity "increasing"; and that is not entirely accurate, for the gravity does not actually increase. But the effect is the same as if it had. What happens is that a body at rest has a tendency to stay there. If it is moved slowly and gradually, the resistance against moving is not great. But if it is moved rapidly, the body does resist and the effect is equivalent to what would happen if gravity did increase. You probably have experienced this yourself. If you have ever ridden a "crack-the-whip" ride at an amusement park, you will remember that on the swings your body was pressed into the seat. This is what happens, but to a greater extent, when a spaceship takes off.

Once a body gets moving, there is a resistance to stopping. Once again a gradual stop works all right, but an abrupt stop is something else again. Perhaps you have been thrown forward when the driver was forced to apply the brakes to a swiftly moving car. This is what would happen in a rapidly braking spaceship.

But whether gravity is actually involved or not, g tolerance is the correct term.

The handling of the g factor now has become an engineering rather than a scientific problem. Wide study has been made of accelerative stress, and much data is available. Working with this data, engineers will be able to come up with gadgets that will give even better protection than we now have.

The opposite of accelerative stress is weightlessness. Weightlessness must be considered in connection with space flight because, once the rockets have boosted the ship free of Earth's gravity, they will shut off and the ship will coast. The ship then becomes what amounts to a free falling body,

and, in this condition, the effects of gravity are cancelled out. The greater part of any space flight will be spent in a weightless condition.

Before the astronauts circled the Earth, there had been a great deal of worry about the effect of weightlessness. And, once again, the astronauts showed that man can endure weightlessness, at least for short periods, without any physical ill effect, and still be in condition to perform his tasks.

But this is only part of the story. On long space flights, weightlessness will have to be considered and provision will have to be made against it.

In the weightlessness of a spaceship some rather weird things would happen.

For one thing, with no weight, the air inside the ship would simply hang where it was. When a man breathed out, the expelled breath would come to rest a short distance from his face. In a few breaths his face would be surrounded by air which he had breathed before. This air would be short on oxygen, the body having used some of it in earlier breathing. It would be rich in carbon dioxide, which would have been expelled with each breath. Within a short time, it would be unfit for breathing. Within a slightly longer time it would be downright deadly.

Therefore a system of fans would have to be used in a spaceship to keep the air in circulation.

Food could be swallowed easily, but keeping it down might be a different matter. Because the valve between the stomach and the esophagus would not function correctly due to weightlessness, any sudden move might bring your breakfast up.

Water could not be drunk from a glass. It would have to be sucked through a tube or straw. Water poured from a glass would form into a sphere and float.

And unless a man was anchored, he too would float.

What weightlessness endured for any length of time might do to the human body is another problem that scientists are trying to work out. There is some evidence that the muscles would tend to get badly out of condition. Under weightlessness, there'd be little work for them to do. Much the same thing might happen to the circulatory system. There would be a tendency to flabbiness in both the muscles and the circulatory system.

It might just be possible that some sort of daily exercise routine would have to be imposed for a spaceman to keep his body in any sort of shape at all.

But, when we come down to the hard questions of life aboard a spaceship, the biggest ones of all are, how do we feed the spaceman? How do we keep his air fresh? How do we manage to pack along enough water to keep him alive?

One man's daily requirement for food, water and air would total out to about ten pounds.

Such a weight is not too big an item on a short trip, out to the Moon and back. Even giving the space travelers a few days on the Moon, the round trip from Earth to Moon probably would not take longer than two weeks. On such a trip the weight of air, food and water would present no problem. We'd just stack it aboard.

But on a longer trip, it would be a different matter. Out to Mars and back would take something on the order of two years and a half. That figures out close to five tons of food, air and water for each man in the crew.

And that's impossible.

On the long trips—and they'll all be long except the Moon trip—we would have to develop something that is called a sealed cabin ecological system.

Ecology is that branch of science which treats of life in relation to its environment—a study of all the interlocking factors which make it possible for things to live.

In creating a sealed cabin system we would, in effect, be creating a liveable world within the spaceship. We would duplicate within the ship all the things necessary to make the conditions there as close to those on Earth as possible.

And in creating these conditions, we would have to consider some factors that, offhand, sound slightly silly.

Dust, for example. We do not know exactly what role dust may play in our lives, if any. We do know that all the air we breathe has some dust in it. We do know that in normal life on Earth dust serves to control humidity. Dust plays a big part in causing rain to fall. Particles of dust serve in many instances as nuclei about which raindrops form. If it were not for dust helping to cause rain, the excess moisture in the air would fall as dew, and a general excessive humidity might result.

Before we devised a sealed cabin system we'd have to know about dust.

We do know that some ionization of the air is necessary to human health. Ionization means that the air has in it some negatively charged and some positively charged particles. It is, actually, radiation at an extremely low level.

Studies have shown that negatively charged particles in limited amounts have a beneficial effect upon the human body. Positively charged particles apparently have a bad effect. However, both may be needed. Just why this is, no one has the least idea.

Some research has shown, but not conclusively, that air completely free of ions will not support life for more than a brief period.

There are methods, a bit too complex to attempt to explain here, which would not only create, but control, the ion content of the air within a spaceship.

Both the matter of the dust and ions may seem to be small things to do much worrying about. The matter of food,

water and air may seem vastly more important. And rightly so, of course. But the space traveler can't afford to pass up anything at all. There would be no point in working out a complicated plan only to have it fail because we had neglected what seemed to be a rather trivial factor.

Luckily, there is at the moment a fairly satisfactory method which not only would provide "home grown" food aboard a spaceship, but at the same time would renew the air.

This system is based upon the algae, one of our simplest plants. The scum you see on stagnant water is composed in large measure of certain kinds of algae.

The algae plan may not be the best one; a better one may be worked out in time. But if man should be able to go into space in the next few years, the algae plan would give him a workable way of life.

The algae would grow in tanks of water. It would absorb carbon dioxide and "breathe out" oxygen exactly as we absorb oxygen and breathe out carbon dioxide. And it could be used as food.

Algae grow rapidly. Twenty-five pounds of algae would provide one pound of food a day. The most promising alga so far tried is that of a family called Chlorella. It is a single celled plant, and is one of the fastest growing of the algae group.

Algae provide protein, carbohydrates and fat, and represents as close to a balanced diet as one can get in any single food. It is rich in vitamins and apparently contains all the necessary amino acids.

No one claims that algae is good eating. It is not ham and eggs nor an ice cream soda. But it is food, and it will keep a man alive. Dieticians have worked out some ways of preparing it so that it is not too bad.

And here again we run up against a peculiar way of thinking that we may have to scrap at times as we go into

space. Most of us eat food because we like it, because it tastes good to us. We seldom eat one thing so often or in such quantities that we get tired of it. But in many places in the world today people eat food not because they like it particularly, but because it keeps them alive. They don't have the varied diet that we do, and couldn't afford to buy it even if it were available.

Spacemen would be in the same situation. They might not like the algae, but they'd eat it because it was food and they needed food.

There have been suggestions that to vary the diet, it might be possible to include slugs and snails in the cabin ecology. The slugs and snails would feed off the algae and the crew would vary their algae diet with occasional snails and slugs. A small Japanese fish which reproduces rapidly also has been suggested as a supplemental diet. The fish lives very happily on algae. Others have suggested that mushrooms might be grown aboard the ship. Mushrooms have little food value, but they'd give some variety.

To grow algae, one needs no soil at all. For growth, algae needs four things—light, carbon dioxide, water and nitrogen. The water need is not great, for the water, through purification, could be used over and over again. Since ordinary air does not carry enough carbon dioxide for the best growth of algae, a small supply might have to be taken aboard the ship. Light would be furnished by the sun. Nitrogen would be supplied by human wastes.

The growing of algae is no simple task. It calls for controlled temperature, plenty of light, safeguards against bacterial contamination. Inside a spaceship such controls would be fairly easy to establish, since the spaceship itself would be a sealed and controlled unit.

With no seasons aboard the ship, the growing and the harvesting of algae would be a continuing process. There

would be no such thing as one crop and then another—the crop would be growing all the time.

It is likely that the equipment necessary to grow the algae would not weigh more than 1,000 pounds.

The whole idea back of the sealed cabin ecology is that the same air, the same water, the same everything would be used over and over again. Chemical filters and distillation processes would be used in part to accomplish this. But the big job would largely be done by the algae, which would feed the spacemen and help renew the air.

Because women consume less food and use less air than men, some scientists have advocated that they be considered as crew members on a spaceship. Figures indicate that women would consume 20 percent less food, water and air than men. This would represent a considerable saving in the load which the ship would have to carry. And there'd be yet another factor: The women themselves would weigh less than men.

Medical records show that throughout life women as a rule are more resistant to disease than men. There are some indications that, properly trained, they might stand up better than men under the rigors one would face aboard a spaceship.

Another possibility of cutting down on the basic supplies which would have to be carried on a ship in space may lie in the mysteries of yoga. Yoga is a bit hard to explain in simple language. It is a philosophy—a way of life and thought. It incorporates religious concepts, but is not a religion. It is practiced in the Far East, principally in India.

The people who practice it go through years of hard training. One of the results which they seem to be able to achieve is a great degree of control over their own bodies.

Studies at the University of Michigan medical center, with a follower of yoga as a subject, have shown that the subject could cut down his breathing rate to four to seven breaths a minute. The normal rate is 12 to 23. By control over

breathing, pulse rate and other bodily functions, a practicer of yoga apparently can reduce his bodily activity by something like a third.

This is reaching way out, admittedly; but if spacemen were able to practice yoga, their intake of air and food apparently would be cut as much as 25 percent.

Nothing has been said here about the various kinds of spaceships we might develop or what power systems we may develop. That is another story and too big a one to try to sandwich into this chapter.

Certainly, man will not have to content himself for too long with the chemical fuel which we are using now.

Someday nuclear power will be tied into the space program. Someday, perhaps, spaceships which now would merely coast through space after the initial thrust, will be accelerated through space by the so-called ion drive.

This does not mean that we would not go into space with what we have today. If we could find a better fuel, it would be just that much easier. If we could devise some alloy that was as tough and strong as steel, but still a good deal lighter, that would help as well—for weight is the bugaboo in getting off the Earth. But these things are not actually necessary. When it comes time to build the actual spaceship, we can do with what we have.

We'll have early failures, of course. But these failures will be due to some gadget or some instrument not working as it should. There'll be nothing particularly wrong with the basic engineering.

The day we get a fuel that will give us steady drive, we'll have our problem solved. No longer, then, will we be forced to hurl tons of metal miles into the sky in one gigantic surge. There is only one reason that a spaceship must gain tremendous speed in a few short minutes: The reason is that we can carry only a limited amount of fuel, and that this

fuel, in the short time that it burns, must shoot the ship out far enough and fast enough so that its momentum will carry it beyond the power of Earth's gravity to haul it back again.

But give us a more efficient fuel—so efficient that we can carry plenty of it for any possible need—and the ship can climb into the sky at a saner pace. And once out in space, with fuel still left, it can continue to build up that pace to almost any speed we wish.

No one knows what this fuel will be. It may be years before we have it. The men or women who will one day discover it may be on Earth today; they may be working on it at this very moment. Or they may not have been born yet.

The job today is to get into space and out to the other planets.

The refinements, and there will be many of them, will come later.

3.

The Origin of Life

IT IS LIKELY THAT MANY OF US, ON STARRY NIGHTS, have looked up into the sky and wondered if there might be people out there—probably not actually meaning people, but life. Wondering if there might be life among the stars. And, perhaps, intelligence.

But those of us who look up and wonder are the people of today. A hundred years ago it would have taken fuzzy dreamers to think a thing like that. Five hundred years ago no one would have thought of it in any seriousness at all.

For this idea of life among the stars is a new idea—pretty much a twentieth century idea. In some respects, a rather late twentieth century idea.

Up until a few years ago scientists felt the chances were extremely small that there could be life elsewhere in the universe. As late as thirty years ago the idea still persisted that our solar system came about as a result of an accident. It was believed most likely that the solar system was formed when another star passed so close to our Sun that tidal action

dragged some of the Sun's material out into space. This material, it was believed, then formed the planets.

The chances of this happening elsewhere in the universe, it was pointed out, were so slight that only an occasional solar system could have been formed. And of those few systems, if indeed there were any, only a very small percentage would have even a single planet with conditions which would permit life to exist.

So the conclusion was that there was almost no chance of life existing elsewhere, for the very simple reason there would be few places where it might develop.

But today the belief has swung around in the other direction. It is now believed that many stars may have solar systems. It is entirely likely that every single star in the universe may have a solar system. (By single star we mean one star by itself—not a double or a triple star.) And if this is correct, it means that there are billions upon billions of solar systems throughout the universe.

Linked with this belief in the existence of many solar systems is the belief that where conditions exist which make life possible, some life is fairly sure to originate and develop. There are even some scientists who will tell you that on a planet where conditions are satisfactory, life *has* to develop—that such development may well be a part of some overriding, universal plan following natural laws.

Of course, not all scientists share this belief in the existence of many solar systems and in the high probability that life will arise on a planet where conditions are right. There is still a difference of opinion. But the trend today seems to be toward a belief in the existence of many islands of life, whereas thirty years ago the belief was fairly general that a solar system was a freak and that life itself also might be something of a freak, to be met with very seldom, if ever, in the rest of the universe.

To most of us it is definitely comforting to believe that we are not alone in the universe, that we may be a part of a general plan which Nature has evolved. One of the first questions which is likely to come up when there is talk of going out to explore the solar system is: Will we find life of some sort? Or, if not life, at least some evidence that life may have existed at one time on one of our neighboring planets?

There is a good chance that we'll find some form of life on Mars—probably vegetation, and of a fairly low order.

But if we find any life at all in the solar system, even if it be no more than bacteria, we can be fairly well assured that life is no uncommon proposition. If it occurs on more than one planet in our solar system, then we can feel fairly certain that it must occur with something like regular frequency throughout the universe.

Dr. Harlow Shapley, one of today's most prominent astronomers, calculates that in the entire universe the minimum number of stars must be ten to the twentieth power—that is, one with twenty zeroes following it.

You couldn't begin to count that many stars in a single lifetime. It couldn't be done even if all the people in the world counted together. If every person in the world started counting now, they would have to count, day and night, for twenty-four hours a day, and keep on counting for four hundred years before they had ticked off the final star.

And this, mind you, is a minimum number—the smallest possible number of stars in the universe. There may be many more than that. Dr. Shapley doesn't even pretend to know exactly how many there may be. His figure is just an educated guess—a very educated guess.

And what, Dr. Shapley asks, is the chance of finding life as we know it among such a mass of stars?

First, he says, you have to calculate how many stars

would have a solar system. Just as a guess, and a very conservative one, he'd estimate one in every thousand. (You will recall that some other scientists are inclined to believe that every single star has a solar system. On that basis four out of every five stars would have some sort of planetary system. Dr. S. S. Huang believes that one in every twenty stars possesses not only a planetary system, but one upon which life would be possible. This would mean that there might be as many as five billion life-bearing planets in our galaxy alone. So you can see how conservative Dr. Shapley is being when he estimates that one in every thousand stars has a solar system.)

Now, continues Dr. Shapley, how many of these planetary systems would have one planet with a temperature range that would make life possible? Once again, the conservative answer is one in every thousand.

Then, taking only those planets having a correct temperature range, how many of these would have an atmosphere and a gravity range which would allow for life? And the answer, once again, is one in every thousand.

And finally: How many of the planets which have satisfied each of these conditions would have not only an atmosphere, but an atmosphere which contained oxygen, carbon, nitrogen and hydrogen?

The answer, as you may suspect by now, once again is one in every thousand.

Bearing in mind that this series of "one in every thousand" answers is designed to represent conservative estimates, we find that we still have, at the end, an estimated hundred million planets which could support life.

Planets, mind you, that could support life—not necessarily planets that have life.

The chances are very great that many of them, if not most of them, do have some sort of life. But just how life

began upon our planet or any other planet is still a mystery to which there is no positive answer—although we seem to be getting just a little closer to an answer.

One of the earliest theories on the origin of life was advanced in 1907 by Svante Aarhenius, a chemist, who envisioned life as something that was continuing and eternal. Life, he theorized, had always existed, and was spread from planet to planet by spores which floated through space.

These spores, escaping from an inhabited planet, would travel, Aarhenius believed, across unimaginable voids, pushed along their way by the pressure of light from adjacent stars. Eventually, although it might take millions of years, the spores would come to rest on other planets. In some cases conditions on the new planet would not be favorable, and no life would result. But in other instances, favorable circumstances would be present and life would arise from the spores, possibly on a planet which theretofore had had no life.

The Aarhenius theory held sway for a short time, then was ousted by new knowledge about radiation. Researchers showed that radiation in space, especially ultra-violet radiation, would kill any spores that might remain in space for any length of time.

With the downfall of the Aarhenius theory, scientists were left pretty much where they were before—without a theory which could explain the rise of life.

The most prevalent belief now is that life arose on Earth as the result of natural processes which involved only the inorganic (not alive) raw material which was present at the time. Evidence now is beginning to pile up which seems to make this premise more and more likely.

At the time life first appeared upon the' Earth, some three billion or more years ago, our planet was a great deal different than it is today. For one thing, there was no free

oxygen. The primeval atmosphere, it is believed, consisted of ammonia, carbon dioxide, carbon monoxide, methane gas and water.

You can scarcely conceive of an atmosphere more deadly to life.

The Earth at that time was also far more radioactive than it is today. Today almost all of the radioactivity held within Earth's rocks has decayed away—but three billion years or more ago, it was still going strong.

Because the ozone layer had not formed in the upper atmosphere as yet—ozone couldn't form until there was free oxygen—ultra-violet radiation from the Sun must have poured down relentlessly upon the surface of the Earth. The ozone layer, a very thin but most important layer in our atmosphere, today screens out most of the ultra-violet rays.

Ultra-violet—the very little that gets through the ozone layer—is the ray, you may recall, that gives you that terrific sunburn every spring. It also is the radiation that killed off Aarhenius' idea of life spores floating through space. If it weren't for the ozone layer, ultra-violet radiation would kill everything on Earth.

But it may be that ultra-violet radiation, strange as it may sound, was one of the factors which played a part in the rise of life on Earth.

Let us first try to set the stage.

Earth, in the beginning, probably was a molten ball. Finally the surface temperature cooled to 2,000 degrees or so, and a crust began to form. Through the ages the Earth cooled; and as it cooled, water vapors and other gases escaped from the hardening crust to collect in great dense clouds which covered the entire planet.

The Earth lay in darkness, all sunlight shut out by the massive clouds. Beneath the clouds the rock cooled and hardened, and the heat slowly drained away.

At times rain fell from the higher clouds where the temperature was cooler; but before the rain could reach the surface of the Earth, it was turned to steam by the heat, still far above the boiling point of water. The steam became part of the clouds again.

Then one day the temperature of the surface fell below the boiling point of water, and the rain started to fall and was not turned to steam.

For centuries it rained, all over the Earth, never stopping for a moment, as the clouds emptied themselves of the load which they had carried for perhaps hundreds of years. It may have rained for a thousand years; it may have rained for a longer time than that.

But at last the rain was finished and the skies were cleared of clouds and the brand new oceans lay upon the surface of the Earth. Water had collected in every depression; it had carved out stream beds as it flowed in raging torrents.

With the cloud cover gone, the Sun blazed down on the new oceans, and on the new mountains which had risen as the Earth's crust shrank and wrinkled.

The mountains were new and the seas were new and so was the atmosphere. With most of the water vapor gone, leaving methane, ammonia, hydrogen and other gases, the air seethed with chemical commotion. New storm clouds formed and lightning lanced across the skies. Volcanoes spouted as the Earth continued to cool.

But there was no life.

The volcanoes shot clouds of flour-fine dust into the sky. It is believed that this dust, too, may have played a part in the origin of life upon this new-made Earth. As the dust hurtled skyward, it probably picked up molecules of methane, ammonia, and hydrogen, and microscopic drops of water. It carried these chemical combinations high above the Earth, up into the region where the ultra-violet rays came raging

in—perhaps more violent than anything we know now, for at that time the Sun was as new and as primitive as the Earth.

If energy was needed to create the first building blocks of life, here was energy in plenty. And here were the raw materials, a witches' brew in which chemical reactions were taking place constantly.

Amino acids, the basic buildings blocks of the protein molecule, probably were one of the first products. But even as the fierce energies of the ultra-violet rays stirred them into combination, the next instant the same energy would ruthlessly destroy them.

Perhaps a tiny fraction of these acids fell into the clouds, which protected them from the solar radiations. And some of these may have fallen from the clouds into protective water.

Century after century they rained down—those which escaped destruction—and collected in the seas.

Century piled on century. A million years went past and the waters of the Earth were thick, like soup, with the fallen amino acids.

This is one way it may have happened. Or it may have been lightning, rather than the ultra-violet rays, which furnished the energy for the creation of the amino acids. They may have come into being high in the atmosphere; they may have been shaped by lightning in a storm cloud; or they may have formed in the water itself. No one can be sure—not yet. Perhaps no one ever will be.

Given amino acids, given other chemicals which were present on the Earth of long ago, given possible combinations of chemical reaction and a million years in which to make it all work out, you can show by chemical deduction how life could have begun on the Earth. The details of the chemical theory involved are too complicated to go into here; but there is evidence which seems to bear out rather

strongly that this was the way life did originate on Earth.

Back in 1953, Stanley L. Miller was a graduate student working under Dr. Harold Urey at the University of Chicago. Intrigued by the possibility that life may have originated through spontaneous generation involving inorganic matter, Miller duplicated in the laboratory the primeval atmosphere of Earth.

He mixed together ammonia, methane, and the other gases, heated the mixture and passed through it an electric spark (to simulate lightning bolts and the radiation from the Sun.)

Miller's mixture, when he put it into his apparatus, had been a deep pink. After a week's time, it turned a murky red. Miller tested it. There was something in it which had not been there before: amino acids.

Life is based on the protein molecule. The amino acids, as we said before, are one of the factors which make up a protein molecule.

But a word of caution here: So far as building a protein molecule is concerned, having an amino acid is equivalent to having a keg of nails as a start toward the building of a house.

So we cannot say that Miller's experiment created life, or that it proved that life had been created in the manner which we have described. But it did show that the assumption of how life may have arisen was correct—that we were on what appeared to be the right track.

Miller, now a member of the faculty at the University of California, did not follow up his experiment. Nor did anyone else, immediately.

But in 1960, Dr. Sidney W. Fox, biochemist at Florida State University, took the next big step.

He wanted to know what had happened to all those amino acids which were making a soup out of the early seas. Dr. Fox mixed together the eighteen amino acids which ap-

parently are common to all living things. Then he heated them, for you will remember that back in the days before there was any life on this planet the Earth still was cooling, and the seas were more than likely warm.

From this mixture he got what he called "proteinoids," which acted a good deal like natural proteins. For example, bacteria would eat them.

Having got his proteinoids, he dissolved some of them in hot water. When the solution cooled, the proteinoids were gone; but in their place were billions of microspheres which resembled a certain type of round bacteria.

And once again, there is no claim that either the proteinoids or the microspheres were alive. But it may have been through steps like this that life finally did appear upon the Earth.

Given the area represented by the surface of the Earth and millions of years of time, there were opportunities for billions of natural chemical reactions. A few of these may have resulted in the appearance of life.

And once there was life, the rest need have waited only upon more time. By slow change, all of the life which is present today upon the Earth could have evolved from a handful of protein molecules.

In the Miller experiment, and again in the Fox experiment, some of the basic conditions for the creation of life were brought into being. The experiments show that some of the things which make up life could have been created in the atmosphere, and under the conditions, which apparently existed on Earth some three billion years ago.

One of the objections which has been raised to this theory of the appearance of life on primordial Earth is that any developing life would have been promptly killed off by the flood of ultra-violet rays pouring from the Sun. The answer to this argument seems to be that if life were

protected by water it would escape the effects of ultra-violet radiation. And almost everyone agrees that the first life upon Earth did pass its early stages in water.

Another mystery is how life could have survived once it was created. All life on Earth today is based upon the energy which comes from the Sun. But to remain alive, an organism must be able to use this energy. Today, the energy is absorbed by plants through a process known as photosynthesis. The photosynthetic process enables plants to use the energy of the Sun to manufacture food for themselves from the raw material which they extract from the soil. All animal life is based upon plant life. While many animals do not eat plants, but live upon the flesh of other animals, the flesh of the animals they prey upon is nourished by plant life.

Photosynthesis is a rather involved process and there is no possibility that the first life on Earth used it to obtain its food. Photosynthesis was a somewhat later development and marked, perhaps, one of the great milestones in the evolution of life. For, with the development of photosynthesis, oxygen was introduced into the atmosphere, since the photosynthetic process involves the giving up of oxygen as a by-product. Slowly, century after century, the oxygen content increased until there was enough of it for oxygen-breathing animal life to develop.

It is believed likely that the first life-forms used what is known as "porphyrin-type" molecules to extract energy from light. Such molecules provide a rather cumbersome way of doing the job and photosynthesis, when it came along, was a vast improvement. But even today there are certain very primitive organisms which still employ porphyrin-type molecules to get their energy. Photosynthesis probably evolved when small changes in the porphyrin molecules led to the construction of chlorophyll, which is the basic agent that makes photosynthesis possible.

A few pages back we used the phrase "life as we know it." We chose that phrase because there is just a bare possibility there may be other kinds of life.

Life as we know it is based upon carbon, with oxygen as an agent. But there have been arguments in the past, and probably will be more in the future, that carbon and oxygen are not the only basis for life.

Silicon (sand is almost pure silicon) has been advanced as a possible basis for life. Silicon, in many ways, resembles carbon. Sulphur might just possibly take the place of oxygen: under different conditions of temperature and pressure, it would have much the same chemical reaction as oxygen. Under other conditions, methane or ammonia might play the role that oxygen plays.

Our kind of life (and again, for emphasis, the only kind of life we know) is based on protoplasm. But by stretching one's imagination to some extent, one can conceive of the possibility that life could be based upon crystals. Certain of the viruses are crystalline in form, and it is possible that viruses may be alive—right at the moment no one can quite decide whether they are or not. Viruses, of course, are the tiny things which cause many diseases when they take up residence in the body and start to grow there.

This business of another kind of life, of course, is largely speculation. It has little evidence to support it. You'd find not too many, if any, scientists who would consider it. And yet it is something to keep in mind, if only for speculative purposes.

If it should turn out that "life as we know it" is not the only kind of life possible, then the probability of the existence of life elsewhere in the universe becomes even greater, and the probable population of the universe increases many fold.

And not only that: life-of-a-different-kind might then exist upon other planets in our solar system.

Life, any kind of life, is dependent upon certain factors. For carbon-based life, these factors are temperature, light, and the presence of oxygen and water.

One of the more important factors for life is the solar constant—the steady amount of heat which is furnished by the Sun.

The solar constant for Earth is about two gram-calories per square centimeter per minute at the top of our atmosphere. A gram-calorie is that amount of heat which is required to raise the temperature of one gram of water by one degree Centigrade. One degree Centigrade is equal to one and four-fifths degrees Fahrenheit, and a centimeter is about two-fifths of an inch.

The value of the solar constant, however, is twice as great for Venus as it is for Earth, and is six times greater for Mercury than it is for Earth. The value for Mars is one half of that for Earth. Jupiter receives one twenty-seventh as much solar heat as Earth; Pluto, way out at the edge of the solar system, only one sixteen-hundredth as much as Earth.

Scientists divide the solar system into three belts of solar heat: the euthermal belt is the belt where the amount of heat is such as to be favorable for life; the hyperthermal belt is that zone which is too hot for life; and the hypothermal belt is too cold.

Earth lies in the euthermal belt, right in the center of it. Venus and Mars are within it, too, but close to the edges—Venus is almost too hot, Mars almost too cold. The planets beyond Mars lie in the hypothermal belt, where the heat is too niggardly to support life. Mercury is in the hyperthermal belt, and far too hot to have any prospect of life.

A similar situation exists regarding light. The light from the Sun is figured at 13,000 foot-candles at the top of our atmosphere. The reading on Venus is 25,000 foot-candles; on

Mercury, 87,000 foot-candles. On Mars the light intensity has dwindled to 5,600 foot-candles; on Jupiter, to 480. Pluto lies in the dimness of only 8.5 foot-candles.

Breaking down the light intensity into zones, as we did heat, once again Earth lies in what we might call the euphotic zone, where conditions are right for life. Once again, both Venus and Mars are on the edge of the zone favorable to life. Mercury lies in the hyperphotic zone, where there likely is too much light to encourage the development of life; while the planets beyond Mars are in the hypophotic zone, where there is too little light.

Venus, Mars and Earth also lie in the oxygen belt of the solar system. This doesn't mean that either Mars or Venus, at the moment, has oxygen. (Both of them may have, but we can't be certain. The discovery of water vapor in Venus' atmosphere would argue that there must be oxygen as well.) But it does mean that conditions were right at one time for oxygen to have been introduced into their atmospheres. The big planets beyond Mars (with the exception of Pluto, which is a freak any way you look at it) have retained their primordial atmospheres, which contain little, if any, oxygen.

The chances are that neither Mercury nor Pluto has any appreciable atmosphere at all.

For water to be usable by life it must be in a liquid form; and here again, Earth, Venus and Mars are in the liquid water belt. Once again, this doesn't mean that either Venus or Mars has any liquid water—it simply means they could have had water at one time. But if Venus and Mars do have liquid water, then they probably are the only planets other than Earth which have.

On the basis of this sort of analysis, it seems clear that when we go out into the solar system we cannot expect to find life on any planets but Mars and Venus.

But there is some evidence that at one time life may have been present on a planet which might have existed between Mars and Jupiter. Whether such a planet ever existed is problematical. At one time belief in the "missing" planet was fairly general. It was believed that the planet had, somehow, been broken up, and that the shattered pieces of it formed the asteroid belt. Now the belief is that a planet tried to form there but couldn't, and that the asteroids in the area between Mars and Jupiter are the pieces of a planet that failed to be born.

Many of the meteorites which fall on Earth originate in the asteroid belt. Others are pieces of debris which may have been circulating through space since the formation of the solar system. A few meteorites may be chunks of rock or iron which have traveled for millions of years from far across space, finally to be swept up by the gravitational attraction of the solar system.

In the spring of 1961, three chemists, Warren G. Meinschein, a research man at Esso, and Bartholomew Nagy and Douglas J. Hennessy, instructors at Fordham University, announced that they had found life-like organic compounds inside a meteorite.

The compounds they found are a type of waxlike hydrocarbons which are found on Earth in petroleum deposits.

Petroleum actually is fuel formed from fossil life. Millions of years ago vast forests and jungles of rank vegetation flourished on the Earth. It was this vast mass of ferns and primitive trees, intermixed with ancient fish and crawling things, laid down year after year after year, which formed the great coal and petroleum deposits which we mine and pump today. Both coal and petroleum came from life; and in petroleum is found the same type of hydrocarbons that the three chemists found in the meteorite. These same hydrocarbons also are found in butter and in presently-living things.

"We believe," Meinschein says, "that wherever this meteorite originated, there was life."

If this is true, then it means one of two things: Either that at one time life existed somewhere in the solar system other than on Earth; or that some millions of years ago another planet circling some far star exploded and hurled some of its fragments, bearing traces of life, far out into space. These rocks, after many ages, finally fell upon the Earth.

The probability that the meteorite bearing the hydrocarbons could be a piece of material from a planet in another solar system seems very slight indeed. A solar system, with its gravitational net, is hard for anything to escape. The force which would have hurled such a piece of material so far out as to enable it to escape its own solar system would have had to have been far more violent than anything we can presently imagine.

The fact that the meteorite which was examined by the three scientists is only one of nineteen meteorites known to contain some carbon compounds makes the possibility even less likely. One piece of material from a planet of another solar system might, just possibly, by a combination of many favorable circumstances, have found its way to Earth. It seems unlikely that eighteen other pieces of debris from this same planet would have.

The best guess, then, is that the meteorites originated in the solar system. Since most of our meteorites originate with the asteroid belt, then that ancient planet which may have exploded to form the asteroid belt may have been the origin of the evidence of life which is found in meteorites.

It is entirely possible, according to theory, for hydrocarbons to be brought into being by cosmic ray action; but surely none so complicated as those found in the meteorite.

At about the same time that the three chemists made their

announcement, two other scientists came forward with other evidence of something very much like life found in another meteorite.

Walter Newton, of the National Institute of Health, and Frederick D. Sisler, of the U. S. Geological Survey, revealed that they had pulverized a piece of meteorite and had placed the dust in a sterile solution to see if anything would grow.

Something did: tiny sausage-like particles about eight-millionths of an inch in length. And they wiggled, or seemed to wiggle. Whether the wiggling meant that they were alive, or was simply a motion caused by the continuing collision of fast-moving molecules, the researchers do not know.

The two scientists, each of whom had worked alone to arrive at identical results, did not claim they had found anything alive. Nor did they claim that since the wigglers were from a meteorite, they must have come from somewhere off the Earth.

They pointed out that they could never be absolutely sure that what they had found might not be something existing here on Earth which had attached itself to the meteorite after it fell. But if so, the wigglers were something new: They were unlike any bacteria so far found on Earth.

Further evidence of life originating at some point other than on Earth was reported in November, 1961, by Dr. Nagy again, this time in a study in which he collaborated with Dr. George Claus, a microbiologist at the New York University Medical Center.

The two reported that they had found in meteorites the fossils of several types of one-celled organisms which resemble fossil algae found on Earth. But while resembling primordial algae, the organisms, all of them so small they must be viewed microscopically, are not of any kind known to have lived on Earth.

The two researchers said in their report they are certain,

in this particular case, that the organisms are not something which might have invaded the meteorites after they had fallen to earth. The fossils were found in meteorites which had fallen from the skies many miles and seventy-four years apart. One of the meteorites fell in southern France in 1864, the other in Central Africa in 1938.

The chances that two meteorites, separated by this time and distance, should have picked up identical contaminations from the Earth is unlikely—and becomes even more unlikely when the organisms which were found do not match any known life on Earth.

All of the above findings do not prove, but they are strong evidence, that life, at least at one time, existed elsewhere than on Earth.

With man on the verge of going into space, it is likely that more and more research will be done in an attempt to determine under what conditions we might reasonably expect to find life on some other planet—either in our own solar system or in some other solar system.

A new science, astrobiology, already has gotten a good deal of notice, and will be getting more. It concerns itself, not —as the name would indicate—only with biology among the stars, but with the study of any life outside of Earth.

When the Russians shot their rocket to the Moon, they announced that they had sterilized it before they fired it, so that it would carry no Earth life to the Moon. If this had not been done, it would be impossible, when man gets to the Moon, to determine whether bacteria found there were Moon bacteria or Earth bacteria. Not that we expect to find bacteria or any other life on the Moon. But just in case we do, we'd like to know for sure that it is Moon life.

And now that we have considered the solar system and the possibility of life there, what about other stars? How far would we logically have to reach out in space before we

found another star which had a solar system where there'd be a fair chance of finding life?

Professor Jan Gadomski, director of the astronomical observatory at the University of Warsaw in Poland, has made a study within the last few years of the stars which lie within seventeen light-years of the Sun. A light-year is the distance a ray of light travels in a year. Light travels at 186,272 miles a second. If you were to figure out a light-year in miles, it would come to about 5,878,000,000,000 miles.

Gadomski studied the fifty-nine stars which lie within this seventeen light-year area, paying particular attention to their size, temperature and radiation. He concluded that about sixteen of them might be the kind of star which could encourage life. He had no way of knowing, of course, whether any of them were circled by planets which might offer a site on which life could develop.

Other estimates place about a hundred stars which are of the type that might harbor life within fifty light-years of our solar system.

This all may sound highly speculative, but to the people at Green Bank observatory in West Virginia, it seems reasonable enough.

Reasonable enough, that is, to be doing something about it.

At Green Bank, a radio telescope installation, a project called Project Ozma has been set up. It is named after the queen in the Land of Oz and its purpose is to listen for signals which "people" on the planets of other stars may be sending out.

A radio telescope is actually a giant radio receiver designed to bring in the noises and signals which are continually coming in to us from outer space. By signals we do not mean the kind of signals which Project Ozma is stretching its ears

to get, but the signals which are sent out by physical occurrences in the galaxy.

All sorts of noises are coming in from the universe and it would seem a hopeless job to listen for "human" signals among all that welter of sizzling and crackling. But the people at Green Bank have narrowed their listening down to one particular wave-length. They are gambling that if there are any signals they will be sent on that wave-length.

The wave-length is 1420 megacycles, which happens to be the 21-centimeter radiation which is sent out by hydrogen. The radiation is emitted when the hydrogen atom becomes excited and the single electron begins jumping down from one orbit to another. It is a distinctive and very common wave-length, because hydrogen is the most prevalent and common of all our elements and is found everywhere, even in the space between the stars.

Scientists believe that any intelligent life, if it wanted to send out signals in an attempt to contact other intelligence in the universe, would recognize the advantage of using the hydrogen wave-length as a signaling band.

The "hydrogen noise" itself is so random that any coded signal sent on the band would be easily recognized and would not be blanked out by the noise of other radiations from space.

When, and if, the signals ever come, they may take the form of mathematics. This is because it is believed that mathematics would be a sort of universal language. Any being intelligent enough to send a signal certainly would have to know something about mathematics. The signals may be counting signals (one, two, three, four). Or they may be simple addition which would indicate intelligence (one plus one equals two; two plus two equal four).

The theory back of the whole project is that other races

in the universe may have reached or surpassed our intelligence level, and, even as we are, may be wondering about whether or not there are other "people" in the universe. If they think at all along the same lines as we do, it would be natural for them to try to contact these other intelligences, to let them know they existed, to say hello to them and to set up communication over many light-years.

If it ever happens, that establishment of communication will be a ponderous affair. Say we pick up a signal from a star ten light-years away. We would answer it. It would take ten years for our answer to be received. If the answer were picked up (and the chances are fairly good it would be, since these other people would be listening for it), it would take another ten years for them to send an answer back. In time, of course, a steady stream of messages would be going out and coming back, but there would always be that lag of twenty years. That is, the answer to any question or any signal sent out today could not be expected until twenty years had passed.

This is one way in which communication could be set up—a simple seeking out of other intelligences, waiting for an answer and then continuing the long-distance conversations from that point.

There might be another way. The intelligent race which was sending out the message might be sending out two streams of messages. One set of signals might be designed to establish contact and at the same time direct a civilization which picked up this signal to another set of signals, on a different wave-length, which would carry vast and continuous quantities of information.

If an intelligent race which had tried to contact other intelligence at a fairly short range of something less than a hundred light-years had failed in this, they might then try for greater distances. In the case of greater distances, they undoubtedly would use the two sets of signals, the one sig-

nal of contact and the second set of informational signals.

At the moment the Green Bank telescope is listening in the direction of two stars, Tau Ceti and Epsilon Eridani, which are considered to be the close-by stars most likely to have solar systems. Tau Ceti is 11.2 light-years distant; Epsilon Eridani is 10.7 light-years away.

The hope, of course, is that other intelligent beings, either on a planet circling one of those two stars, or on a planet of some other nearby star, may have picked our own Sun as a star about which it was likely a solar system had developed. And that these beings even now are beaming a signal toward our Sun, in the belief that another intelligence might have developed here and would be waiting such a signal —which we are.

The hope, however, is only a hope. We have no reason to actually believe there are intelligent beings on either Tau Ceti or Epsilon Eridani. Our hope is based entirely on the belief that here are two stars which have a fair chance of having solar systems. If they have solar systems, there is a fair chance life has originated there. If life has originated, there is an outside chance that intelligence also has arisen.

Dr. Sebastian von Hoerner has estimated that probably no more than one star in three million would have a civilization sufficiently advanced to try to seek out other intelligence. Even on this estimate, however, there would be billions upon billions of such intelligences in the universe.

Time is another factor which would enter into the chances of one civilization contacting another. Only in the last few years have we been capable of even thinking about listening for the signals of other intelligences. Even now we may not have the right kind of equipment to receive these signals—for they do not have to be radio signals; they could be something else, some other means of communications of which we as yet know nothing. And should we now pick up

intergalactic radio signals, we have, at the moment, no equipment which would allow us to reply. We probably could develop it within a comparatively short time; but right now we haven't got it.

Civilizations rise and die out. There is no great probability that the intellectual peaks of many civilizations would coincide. It would have done another intelligence no good to try to contact the Earth, even with radio (which we know) before we had reached a proficiency which would allow us to pick up their signals. There have been only twenty-five or thirty years in which we could have picked up such signals.

It is probable, also, that civilizations may have only a short time in which they would be either interested or capable of contacting another civilization. The chances are that all intelligences would take a long time to develop to a point where they would have the instruments to signal other stars. This time of capability and interest might last only for several thousand years, at which time the civilization would lose interest in scientific and technical matters and would enter another period of its development, in which the contacting of other intelligences would have no part.

Or there may be the seeds of self-destruction in all civilizations, as some people think there are in ours. Civilizations may reach points where their destruction is almost inevitable. If this is true, they may, once again, have only a short time during which they are able to attempt the contact of other intelligences.

Or there may be many civilizations which have tried to contact other intelligences. They may have tried for years and failed of any contact. Although still interested and capable, they may have given up, convinced that there are no other people they can reach.

But even in spite of all these probabilities, there is vast interest among Earth scientists in the possibility of such a

contact. So great is the interest that an unannounced conference was held quietly in November, 1961, under the sponsorship of the National Academy of Sciences, at Green Bank to review the situation.

There are astronomers who see in the contacting of another intelligence the possibility of working out our own problems—of saving our own world from self-destruction. We might learn from another intelligence how to go about living in peace among ourselves. And even if there were no such formula of world peace, the knowledge that there were other people in the universe might serve to turn men's minds outward from themselves and their own problems and to work together in establishing good relationships with our brothers (in spirit, if not in body) many light-years distant.

This much must be said: We are only at the beginning of our attempt to establish acquaintanceship with these brothers of ours in farther space. We are very much like the tiny tribes of men who at one time were scattered over the face of the Earth. Even had these tribes known there were other tribes, contact would have been difficult and, in some cases, impossible. The only means of travel was walking. There were great rivers and mountains and deserts, and in some cases oceans, to be crossed before two tribes could get together. But eventually the tribes did get together to form the great family of men which now inhabits the earth. Proportionately, we are in no worse position to contact other men far across space than one tribe of men a half million years ago would have been in the contacting of another tribe a thousand miles away.

If we believe that life may exist on many other as yet unknown solar systems, then it must follow that intelligence also should exist. On some of them, that is; certainly not on all of them. For life doesn't have to be intelligent. As a matter of fact, most life on Earth is not. The plants and the lower orders of animals are not. Intelligence on Earth has appeared

only in the warm-blooded, oxygen breathing animals. Man's own form of intelligence (the only kind which we could contact), the culture-building intelligence, would appear less often than an intelligence such as that of dogs, porpoises, elephants and other creatures here on Earth.

Intelligence would not necessarily be the end result of all life systems. But since it did appear on Earth, there is every reason to believe it would appear elsewhere as well. The observations of science seem to indicate that evolution produces organisms to fit every nook and cranny of an environment. Is it too presumptuous to think that intelligence has a nook or cranny of its own in all environments? If this should be the case, then the possibility of intelligence becomes much greater than otherwise.

In writing of these other intelligences we have in places called them "people" or "men." Perhaps the terminology is not so ill-advised, at that, for they would be people in the sense that we could communicate with them and, perhaps, in time, come to understand them. As they, we hope, would come to understand us.

But in thinking of them as people, we should not think of them as human beings. It is most unlikely that we would find another creature like man on any of the unknown planets which circle other stars. Intelligence need not necessarily be confined to the shape of human beings.

You will find those who argue that since man has proved successful on Earth, there is reason to believe that a creature of similar shape should develop and prove as successful on some other planet.

Such an argument usually points out the advantage of two legs, of a brain located in the head, of a head located at the vantage point of some six feet above the ground, and of the fine flexibility of the hands.

This is man speaking with all the bias, all the prejudice, all the narrowness of a one-planet point of view.

As a matter of brutal fact, man's body is not as successful as we would like to think. In a lot of ways it is badly engineered. In some ways it is like a jerry-built house, put together with a rush because the carpenter was in a hurry.

Because man is a newly developed creature as compared with, say, the cockroach or the opossum, his body is still not well adapted. It hasn't had the time to adapt as it would have under more deliberate progress. Man stood erect because he had to free his hands—that is, he had to free them if he was to become the sort of creature that he is today. Man, of course, didn't actually do it—Nature did it for him. He went through a process called evolution, which is Nature's way of building what she wants.

So we stood erect and hoisted our heads up in the air, where they are an easy target for anything that is thrown at them. We turned our internal organs on end as no other sensible animal, with the exception of our cousin primates, would ever think of doing. We exposed the soft front part of our bodies to possible attack. We put an undue strain on our legs, which now must do double duty—two instead of four.

As a result of all this we are plagued with many ills. We have varicose veins. We have aching backs. Our sinuses are bad. Our skull is thin and very crackable. If Nature had been intent on doing a good workmanlike job, she would have built for us a thicker and more rugged skull to protect our brain, which is the very thing that makes us different from all other animals. But she was in too much of a hurry to tend to things like that.

It is unlikely that Nature, on any other planet, would have made the same mistakes with another intelligence as she

made with us. Other mistakes, perhaps, but not the same mistakes.

If we could go back into our history and retrace, step by step, the process by which man became what he is today, we would find many turning points in the evolutionary scheme. If, at any one of these points, man had taken a different direction, he would have turned into something other than what he has become. Man is an evolutionary creature. It is simply asking too much of probability that some other creature, on some other planet, should have followed the same route man followed to become another man.

A cockroach has been a cockroach for millions of years; an opossum has been an opossum for almost as long. Man's history is short as compared with either one, and he has not "stayed put." He has changed with astounding rapidity, not only in the development of his mental ability, but in his body as well.

Given all of time and space, theoretically everything which possibly can happen will happen at least once—maybe even twice. There is the old saw which asserts that if all the monkeys in the world were put down before typewriters and made to pound haphazardly at the keys, they eventually would produce all the major works of literature. Given all of time and space, they'd have to.

But we haven't had all of space and time. Our universe has had only ten billion years or so. According to one theory, that is. According to another theory, we live in an eternal universe, which had no beginning and will have no end. And if that is true, then it would be just barely possible that man has risen in other days and other places—but probably so separated by time and distance that one group of men would never meet another.

We have to assume that for a creature resembling man to appear on another planet, that planet would have to be exactly

like ours and its evolution would have to have followed exactly the same course. The odds against such a situation become apparent when we consider the trillions of ways in which a planet could differ from Earth, and the trillions of paths which evolution could follow.

The whole contention that an intelligence must be manlike is pointless in any event. The important thing is not the shape which an intelligence takes, but that it is an intelligence, that it can think and communicate.

We search continually for purpose. We ask why such and such a thing may happen; what purpose does it have? Apparently there always is a purpose. Science has shown us that in everything which we have managed to understand there is an unbroken pattern of order and of reason. So far, in the entire universe, we have found nothing which has turned out to be entirely purposeless.

And if everything else has a purpose, as our research so far would indicate, then intelligence must also have a purpose.

It has been said in recent years, when nuclear weapons are discussed, that man is the only species on this Earth which has ever invented the means of wiping himself out.

Might it not be better, with man on the verge of space flight, to say that man, along with the probable other intelligences of the universe, may have a higher purpose than wiping himself out? May it not be that he is intended as a moving influence in the vastness of the universe, and that his going into space may be the first real step in this direction?

Might it not be that man, in being so fashioned that he cannot turn his back upon the unknown, is in effect an evolutionary process that in the fullness of time may change the entire concept of the universe?

It may be that man was never meant to spend all his years on Earth. Earth may be no more than a cradle for him.

4.

The Beginning of It All

ASK ALMOST ANYONE WHAT THE SOLAR SYSTEM IS and he is apt to tell you: "It is the Sun orbited by nine planets."

And that is right, of course. But it's a great deal more than that.

The solar system is a wonderful mechanism—the sleekest engine you have ever seen. It operates by natural law, in an orderly manner, and it has been running for five to seven billion years. It will operate for uncounted billions more. Although, so far as life on Earth is concerned, we probably have only about five billion years more we can absolutely count on.

That shouldn't worry man too much, however. Since the first thing that could even remotely be called a man first walked the Earth, less than a million years have passed. We have thousands of times as many years left as we have lived. And by the time Earth becomes unlivable we should have figured out a way to go somewhere else, if need be.

The solar system is composed of a star (the Sun), the nine planets, thirty-one moons, upwards of fifty thousand asteroids, vast numbers of meteors and other assorted junk, perhaps as

many as a hundred billion comets, and great clouds of radiation floating out in space.

When we call the solar system a mechanism, we don't mean that it is sitting there, idly spinning like a wheel. It is on the move and going very fast.

All the planets are spinning on their axes, some quickly, some comparatively slowly. Each is moving about the Sun in something that is called an ellipse, which is, roughly, a slightly off-true circle.

The Earth spins on its axis at the rate of 1,000 miles an hour—measured at the equator. Because of the Earth's shape, the speed is less as you go either North or South. In the United States, the average speed would be about 750 miles an hour. At either the North or South pole there'd be, theoretically, no speed at all.

In addition to this, the Earth is moving around the Sun at the rate of 66,600 miles an hour.

The Sun itself is moving through space, carrying the entire solar system with it, at 43,000 miles an hour. And the little cloud or neighborhood of stars to which the Sun belongs is moving at a speed of 630,000 miles an hour, swinging in a great circle around the center of the galaxy of which this cloud of stars (and the Sun and Earth and every one of us) is a part.

Even moving at this speed, the Sun and its neighbor stars will need something like 200,000,000 years to swing clear around the great wheel of our galaxy.

Perhaps the galaxy itself is moving, too—we're pretty sure it is. But what its direction and its speed are, we have no idea. It is just too big to measure.

The Sun and our solar system are way out in the suburbs of our galaxy. We're about 25,000 to 30,000 light-years from its center. Our galaxy, which we call the Milky Way galaxy, probably contains about 100 billion stars.

Our galaxy is only one of many. The biggest telescope in

the world, the 200-inch Hale at Mount Palomar observatory, ordinarily can reach out about two billion light-years. There is no sign, at that distance, that we have anywhere near reached the end of the galaxies.

In the summer of 1960, the 200-incher picked up a very faint luminosity—faint because it was so far away, but actually bright beyond all imagination, because if it had not been it would not have been seen at all—at an estimated distance of six billion light-years. It was believed to be the light of two colliding galaxies—billions upon billions of stars rushing in upon each other.

If the galaxies were colliding six billion light-years out, then it stands to reason that there must be galaxies, perhaps too faint to be seen, existing between the edge of our ordinary seeing limit of two billion light-years and the six billion light-years where the raging radiations of colliding galaxies were strong enough for us to see them.

There is no way of knowing how many galaxies there are. More than a billion have been counted by our telescopes. Some astronomers estimate that about a trillion galaxies may lie within the range of our biggest telescopes. And this is only within the range of our "seeing." How many lie beyond we can't even come close to guessing.

This great collection of galaxies, extending beyond our ability to "see," is the universe. Each galaxy in turn is a collection of billions of stars. Our galaxy, with its 100 billion, is somewhat larger than the average galaxy.

Our Sun is a fairly ordinary star in size and temperature. But there are many other kinds of stars. Many stars are double stars and even triple stars—that is, two or three stars revolving about a common center of gravity.

And what's the story behind all this, you ask? How did this all get started? Where did it all begin, and where will it all end?

These very questions highlight one of the liveliest arguments the scientific world so far has experienced—and there have been, in the course of scientific history, a lot of lively rows.

The argument involves two theories: the theory of the evolving universe and the theory of the steady state universe.

The concept of the evolving universe starts with the "big bang" theory. This theory say that at one time, billions of years ago, all the matter and all the energy which is in the universe today was wrapped up into one gigantic mass.

The material in this huge mass was packed together into the smallest space that was possible. Everything was absolutely jammed together. There was no room between anything at all.

No attempt is made by the proponents of this theory to explain where all of the matter and energy came from, how it was created to start with, or how it came to collect in one particular spot.

We call it material, but it is likely that there was little material or matter involved. At one point, near the time of the "big bang," the mass may have been composed almost entirely of radiations (light and ultra-violet and gamma rays and perhaps many others). The radiations were crammed so closely together that the temperature of the mass was several billion degrees.

At this temperature, matter could scarcely exist. It could try to exist, but the odds would have been all against it. Any attempt of atomic nuclei to form would fail because of the intense gamma rays, which would shatter any particle as fast as it could form.

To realize what the situation probably would have been like, let's go back to the atom. You may remember that an atom is composed of a number of electrons orbiting about a nucleus. There is a lot of space within the structure of an atom. Relatively speaking, electrons spin about at a greater

distance from the nucleus than the planets from the Sun.

Let us say, then, that we take an atom and squeeze the electrons down on top of the nucleus. Then let us give the whole thing an extra potent squeeze to force the components of the nucleus to collapse upon themselves. In other words, let's squeeze all the space out of an atom and leave nothing there but the "matter" of which the atom is formed. The word "matter" is just a little awkward and misleading, for perhaps it isn't matter; in fact, we rather think it's not.

You or I, of course, could never accomplish this squeezing of atoms. But there are conditions which can. A similar, but not nearly so drastic, situation exists at the center of our Sun, where the atomic material is fairly well squeezed together. There are other stars throughout the universe where the atomic material is squeezed together much more tightly than it is in the Sun.

Say someone or something took the Earth and squeezed it together so that absolutely no space existed among the atoms of which it is formed. When they got through with it, when they had it squeezed dry of all space, the Earth would be less than 1,800 feet in diameter.

Do the same thing with the Sun and it could be squeezed from its present diameter of 864,000 miles to a diameter of 25 miles.

This, then, theoretically, is the situation which obtained at the first beginning, according to the "big bang" theory.

Here was this ball of energy, possibly 1,700,000,000 miles in diameter, a seething, raging mass of radiation of a density which cannot even be imagined. A spoonful of it would have weighed many tons.

And yet it was not matter. It was radiation. It is hard to conceive of a spoonful of X-rays weighing many tons—but that, very roughly, is what we are asked to imagine.

The scientists have a name for this material. They call it

"Ylem"—but that is a term used only in connection with the situation at the beginning of the universe. Some scientists call the great mass of "Ylem" the "cosmic egg."

How long the great primeval mass existed no one has the the least idea.

But suddenly something happened. Something triggered this mass of radiations, and there was a titanic explosion which blasted the energy and the radiations out into space and in all directions.

This explosion, this big bang, say the advocates of the evolutionary theory, was the creation of the universe.

In the first five minutes, with the energy and the radiations streaking outward at tremendous speeds, the temperature dropped to something like a billion degrees.

With the fall of the temperature, particles and atoms were possible and immediately began to form. The first, probably, was hydrogen, the simplest atom of them all. Then helium and lithium and the other lighter elements. As the temperature dropped even lower, the heavier elements also were able to form—but as gases. There was as yet no solid matter anywhere.

By the end of the first half hour all the elements had formed and creation had been accomplished.

For thirty million years the gases and the radiations and the energy fled outward, spreading out, thinning out, getting cooler all the time.

And as the temperature continued to drop, one day some of the heavier elements began to condense as solid matter.

On that day (although day may not be the word) some thirty million years after the big bang, the temperature had fallen to 80 degrees or so. By that time all the elements which were going to condense out had condensed out, and there was dust as well as gas, great monstrous clouds of dust.

There was a coldness and a darkness. There was no longer

any light. Night had fallen on the universe. And in this coldness and darkness the clouds of gas and dust still moved outward from the center of the explosion, but at a slower rate.

Nothing further happened for a while—no one knows how long. One guess is 250 million years.

And the big bang, how long ago was that?

There was a time when it was believed to have happened only a couple of billion years ago. But the time is being pushed back all the time. Now the best estimate seems to be around ten billion years ago. Although that's not a very solid guess. Some evidence brought in just recently points to twenty-five billion years as a better guess. There are some people who think that a trillion years may be closer to it.

So for 250 million years after the thirty million nothing much happened. But things were getting ready to happen. The dust and the gas were getting cranked up so that something could happen.

Gases resulting from any explosion have a tendency to spin.

During those 250 million years when nothing much happened the gases were spinning, and, in their spinning, were sucking in and gathering up the vast clouds of dust which were scattered throughout the universe.

As more and more dust was sucked in and more mass was added, the spin became faster and began to tighten up. The big clouds of spinning gas and dust broke up into eddies—not little eddies, but gigantic eddies, thousands of light-years across; for the original spinning masses were greater than anything we can begin to describe.

At the end of millions of years there were uncounted numbers of these dust-and-gas whirlpools, spinning faster and faster, becoming denser and denser as the matter pulled together.

Inside the whirlpools other eddies formed and squeezed

together even tighter. With the increase in density, gravitational forces would have increased, pulling the dust and gas masses even more closely together.

And now, as the pressures rose, the cold masses began to heat up. Finally they began to glow. The universe was no longer dark. Light had come back again.

Faster spun the whirlpools. The matter became even denser. The glow deepened. The temperature rose. In some areas it reached up to twenty million degrees or so, and there were shining spheres, hurling out light and other radiations. The stars were being born.

One by one the lights came on across the universe. Slowly at first, perhaps, and then faster and faster, as more and more stars came into being, with each whirlpool becoming a galaxy sheltering billions of burning stars.

Apparently the galaxies are still fleeing into the outer reaches of the universe—ours among them, although it appears there are a lot of galaxies which have had a good many billions of light-years head-start on us.

Our telescopes show that the farther out the galaxy may be, the faster it is moving away from us. Some of those out at the very rim of our seeing seem to be moving at nearly a seventh of the speed of light. The colliding galaxies caught in the Hale telescope at the apparent distance of six billion light-years seemed to be moving at half the speed of light.

In other words, the energy of that big bang is still in operation. The fragments still are flying.

But there is some suspicion about the speed which the far-off galaxies seem to have. There is just a possibility they may not be going as fast as they seem to be.

Light moves at the speed of 186,000 miles per second and is one of the constants upon which scientific measurement is based. Light *always* moves at 186,000 miles a second. It is one of the few things you can count on.

Or can you?

Would it be possible that even light gets tired, that after it has traveled for over two billion years it slows down a bit? Some scientists have suggested that this may be the case. And if it is, that would mean that we have been measuring the speed of the outer galaxies with "slow" light, and that the galaxies are actually moving more slowly than they seem to be.

Most proponents of the theory of an evolving universe believe that the universe had its origin in the big bang, and that matter and energy are being spread thinner and thinner throughout space. They believe the day will come when all energy will be dissipated, and that the universe will then die.

There was a beginning. There will be an end. And that is all there is. There isn't any more.

But there are others who believe that this is something which may have happened time and time again—that we have a "pulsating" or an "oscillating" universe. They theorize that the outward fleeing of the galaxies will some day come to an end, that the big bang will play itself out and that all matter, dead long since, will then start pulling slowly back together. Scarcely moving at first, then faster and faster, until at the end of many billions of years it all will be rushing back at a tremendous speed to gather once again into another mighty mass of matter. And in time this matter will compress itself together, and in time it will change into energy and radiation.

And when that happens there'll be another big bang and it will start over once again.

And if that should be the case, then there has been a Universe I and a Universe II and a Universe III, up to no one knows how many. There is no way of knowing.

Opposed to the evolutionary theory of the universe is the theory of the steady state universe.

The theory of the steady state universe says that there

was no big bang, that there was no beginning and that there will be no end.

The theory is that the universe has always been in existence, that it always will be in existence. It says that both time and space are infinite—that they, too, had no beginning and will have no end. And, say those who stand by this theory, matter is being continually created throughout all of space so that as the galaxies expand into infinite space, the space between them and other galaxies will be filled with new galaxies formed out of newly created matter. Thus, no part of space ever will be left empty by receding galaxies, but the distribution of the galaxies throughout all of space that is occupied will be uniform.

The evolutionary universe is an expanding universe because of the impetus given by the violence of the explosion which started it all. The steady state universe also is an expanding universe, but it is expanding because of the creation of new matter which constantly fills in the spaces between the galaxies as the older galaxies move away from one another.

The new matter which is being created, according to the theory, is our old friend, hydrogen, which is the basic building block of the universe. It is believed possible that the very creation of this new matter in the areas between two or more galaxies may create the pressure which forces them apart, thus making room for the new matter to form a galaxy of its own. There is some belief that the creation of matter may also result in the creation of space, and that as matter is created space may tend to "pile up" between the galaxies, forcing them apart.

All of this, of course, would take billions of years. The formation of new matter is no overnight affair. But given great volumes of space and long stretches of time, a vast amount of matter would form; and, as this matter began to pull together, we would have the beginning of a brand new galaxy.

For many pages now we've been a long way from home. So let's get back to our own solar system. Large as it may be, it seems a fairly cozy place after wandering so far into the depths of space and time.

We've been having a look at how the universe may have been formed. What, then, about our solar system? For the solar system, even in a steady state universe which goes on forever and forever, was created at some time in the past. For it is the universe which goes on and on forever, not the solar systems in it. The solar systems, like the cells in our body, are created and die, no matter what kind of universe we may have.

The best estimate is that the solar system was formed some five billion years ago. Four and a half might be a good guess; seven might be as valid. But since no one knows for sure, five makes a good intermediate number.

The probability seems to be that the solar system was formed in the same manner as were the galaxies. And, once again, formation of the individual galaxy theoretically would be pretty much the same under either the evolutionary or the steady state universe.

The solar system probably was formed out of a cloud of dust and gas. The first theory which advanced this origin was called the Kant-Laplace theory. When it ran into some difficulties, it was replaced by what is known as the Weizsacker theory. The Weizsacker theory stipulates that the solar system was formed out of innumerable eddies of gas and dust rather than out of one large cloud of it.

Two things may have happened. The dust and gas may have existed about the Sun at the time it, itself, was formed. Or the already-formed Sun may have collected the cloud of gas and dust by passing through a dust cloud and dragging some of the dust and gas along with it after it cleared the cloud.

What happened, in either case, was very much the same thing that happened in the formation of a galaxy. The dust and gas formed itself into an eddy pattern, with the solid matter condensing into masses.

The heavier material collected in the center of the masses, leaving extensive "atmospheres" of lighter gases around the central condensation. These balls of gas and matter, one school of thought believes, were many times larger than the planets as they are today. They are called proto-planets. The Earth, at first, may have contained 1,000 times more material than it does today.

Radiation pressure from the Sun would have tended to blow away the greater part of these extensive early atmospheres. In other cases, lighter gases would have escaped the less massive planets. Thus Earth, because it is not as massive as Jupiter and the other giant planets, lost a great part of its early material. The giant planets, because they were more massive, were able to retain a great part of their atmospheres. Today, on Earth, we live on what amounts to no more than the core of the early proto-planet.

The condensation and compression of the material which went into the making of the planets heated up the material, but did not set off the nuclear reaction which has kept the Sun burning for billions of years. In time the planets cooled, and became as they are today.

The extent to which the planets heated up is a matter of some difference of opinion in the scientific world. At one time, just a few years ago, it was fairly well settled that most of the planets were molten to start with. Now the belief seems to be swinging around to the opinion that while most of the planets were hot, they probably were not molten.

There also is belief in some quarters that the planets may never have been hot—that they were formed by the steady sweeping up of free material flying around in the solar system

space. This process is called "accretion," and envisions the steady growth of a planet by a mechanism not dissimilar to that which makes a snowball grow when it starts rolling down a hill.

And there is also another school of thought which believes that there were no planets at all to start with, but a number of much smaller objects emerging from the eddy patterns. The planets, it is believed, were formed by the collisions and drawing together of a number of these smaller bodies. This belief fits in with the theory of accretion, for the bigger masses which resulted from the collisions would have continued to sweep up all sort of junk as they rolled about the Sun.

Dr. Urey has suggested that our Moon may have been one of the original masses which emerged from the eddy pattern, that it somehow escaped collision with any other large mass, and later was captured by Earth and became Earth's satellite. If this is the case, then the Moon is older than the Earth by, perhaps, a hundred million years.

If the accretion theory is correct, then the planets barely heated up at all. That is, from a human point of view they were most likely hot; but they were nowhere near the molten stage.

Molten or cold, we do know that the probability is that in the early years of the solar system space must have been filled with a lot of random junk. For years huge meteors and planetoids (too big to be meteors, too small to be planets) must have whizzed around until they found a resting place by plunging to the surface of one of the developing planets. Today the solar system, compared with what it was to start with, has been fairly well vacuum-cleaned by the attraction of the larger bodies.

Scientists believe that the solar system could have been

formed, and stabilized in about its present situation, in something like a hundred million years.

Some years ago there were several other explanations for the formation of the solar system. They all came under the heading of "catastrophic" or accidental origins. All of them are largely discredited now.

The most popular one was that another star passed sufficiently close to our Sun to haul out into space, by tidal action, great gobs of material from the Sun. This material, spinning around the Sun after the intruding star had disappeared into space, finally formed itself into the various planets.

Another theory saw the actual collision of the Sun with a large body wandering in space, a body big enough to make a considerable splash when it hit the Sun and hurl out the material which in time became the planets.

The presently accepted theory of a gas and dust cloud coalescing into planets seems by far the most reasonable. Theoretically, it checks out; scientists, with the use of mathematics and natural law, can show how it happened. Which doesn't mean, of course, that it has to be right. But there is a high probability it is.

For some time there was considerable doubt about one factor in the gas and dust theory—the question of angular momentum. That seems to be fairly well covered now by the present theory, although every now and then the question is still raised.

Angular momentum, in a spinning body, is a product of the mass and the distance from the center. It can be illustrated in the case of a skater who is spinning on the ice with arms outstretched. When he lowers his arms and pulls them in tight against his body, the speed of his spin increases. This can be explained by something called the conservation of angular momentum. That is, as the distance factor in the spin-

ning body decreases, the speed of the spin increases. If the skater thrusts out his arms again, the distance factor increases and the speed of the spin slows down.

In the solar system, the Sun rotates too slowly in relation to the motion of the planets. The Sun, with the bulk of the mass in the solar system, should likewise have most of the angular momentum. By rights, it should be rotating once every 12 hours instead of once every twenty-seven days.

The planets and the rest of the solar system other than the Sun add up to slightly more than one tenth of one per cent of the system's entire mass. Yet this one tenth of one per cent has almost 98 per cent of the angular momentum in the system.

The original dust and gas cloud theory of the formation of the solar system was advanced by Immanuel Kant, a German philosopher, in 1755. In 1796, the French astronomer, Pierre Simon de Laplace, working independently, developed it in more detail.

They envisioned a gas and dust cloud spinning and contracting as it spun. As it contracted it spun faster, in accordance with the law of the conservation of angular momentum. When the speed of rotation reached a certain point, it threw off a ring of matter from its rapidly rotating equator. With the ring of matter thrown off, the speed of spin slowed down, since the throwing off of the matter had gotten rid of some of the angular momentum. But the cloud now contracted further and the speed once more increased until another ring of matter was thrown off. As time went on, the spinning cloud left behind it a series of such rings and these rings, said the theory, eventually condensed into planets.

But with this process of forming a solar system, the matter of angular momentum as it existed in the solar system was impossible to explain. The Sun should have had the lion's share of it, while in fact it had very little.

In 1944 Carl F. von Weizsacker, of Germany, came forward with his theory that the dust and gas, instead of remaining in a large cloud, formed into a number of relatively small eddies. These eddies, in turn, broke up into even smaller eddies.

Friction between the eddies upset the angular momentum function. The faster-moving inner portions of the forming solar system slowed down and the more slowly moving outer portions sped up. Angular momentum, in other words, was transferred out from the center.

Under this sort of a beginning, the reason for the Sun having so little of the angular momentum becomes possible to understand. Although it still sticks in the throat and while the Weizsacker theory is generally accepted, there still is that feeling that the whole story may not yet be told. Many scientists still are just a bit uneasy about the Sun coming out with so little spin.

So finally we have the planets in position and moving about the Sun. They are moving under their own momentum, but they are tied to the Sun by its gravitational force which keeps them swinging about it. If it were not for this gravitational force, the planets and everything in the solar system would go shooting off into space. That is, they would tend to travel in a straight line rather than around the Sun.

If you have a ball tied to the end of a string, you can swing the ball around in a circle. If it were not for the string, the ball would not travel in a circle. If the string should break at any point, the ball would go shooting off in a straight line, continuing in the direction it was moving when the string broke. Or you can let go of the string and the same thing will happen.

Keep the string short and the ball moves swiftly. Lengthen the string and the ball is inclined to move at a slower pace. The same thing, approximately, is happening in

the solar system. The planets are moving in a circle because the string of the Sun's gravity hold them to that path.

At first, perhaps, the solar system was not as orderly as it is now. There may have been planetoids and planets traveling about the Sun in erratic paths. As time went on many of these bodies must have collided, thus eliminating one or the other, or both. Some of the bodies were broken up; others were absorbed by larger bodies. Finally, after several millions of years, the system settled down. Only those bodies which did not interfere with the orbits of others remained. The Sun took a tighter rein on his family and pulled them into stable paths. And we had the solar system that we know today.

If there is anything striking about our solar system it is the perfect order which it displays. Order is apparent even in the evenly spaced distances between the planets. This orderly distance is explained by something that is called Bode's law. Actually it is not a law—it is simply a mathematical formula which predicts where a planet should be.

Taking the Earth's distance from the Sun as the value of one, Bode's law says that Mercury should be positioned at 0.4 of that distance (it is at 0.39), that Venus should be at 0.7 (it is at 0.72) and that Mars should be at 1.6 (it actually is at 1.52). The agreement with the so-called law is fairly good throughout the solar system except that there is no planet between Mars and Jupiter, where the law says that one should be. But there is the asteroid belt, which may represent a planet which failed to form, or one which was destroyed.

There is one serious disagreement: Neptune, which, according to the law, should be at a distance of 38.8 astronomical units from the Sun (an astronomical unit is the distance between the Earth and the Sun), turned out to be only 30.07 astronomical units from the Sun. But Pluto, when it was discovered, checked in at 39.46. There is some belief that Pluto

may at one time have been a moon of Neptune's which escaped. This may account for the disagreement with Bode's law. Pluto's orbit, alone of all the nine planets, is out of kilter. It is tilted at an angle away from the plane in which the other planets lie, and its orbit is extremely sloppy.

Except for Pluto, all of the Sun's planets do lie in the same plane, all in line with the Sun's equator. And even Pluto's orbit is canted just a little.

Another point of order: All the planets circle the Sun in the same direction—in a counter-clockwise motion if you look down at the system from a point above the Sun's north pole.

With the exception of Uranus (and, possibly, of Venus), all the planets rotate upon their axes in the same counter-clockwise direction. The Sun also rotates in the same direction. Uranus doesn't rotate in a clockwise direction. Rather it lies almost on its side, with one of its poles pointing at the Sun, and rolls along the planetary plane like a marble rolling on a floor. Venus may, just possibly, rotate clockwise.

And to keep the orderliness of the entire system intact, all the moons which circle their planets, with a few exceptions, also orbit their planets in the equatorial plane and in the old reliable counter-clockwise direction.

Pluto, the farthest-out planet which we know of now, is an average of 3,666,000,000 miles from the Sun, which makes the diameter of the solar system close to seven and a half billion miles. And this does not take into account the comets, which also are members of the solar system. Some of them may reach out in their long orbits to many billions of miles beyond the Sun.

But even with nine planets, thirty-one moons, and the vast litter of junk, and the comets, we must not think of the solar system as being a compact mass. It is very far from that. It is as if we had taken a pinch of sand between our fingers

and sprinkled it very sparingly over the floor of a huge room.

Except possibly in some areas which lie between the galaxies, space is never completely empty. There always is a wandering hydrogen atom or a tiny piece of debris or a cosmic ray—so we have to say that space usually does contain something. But if it isn't empty, it's just this side of empty.

The solar system, by deep space standards, is a cluttered place; but let's try to see what we actually have in the solar system.

What we are about to do is a little trite, for every other book on the solar system has done the same. But since it is an effective method of showing the distances involved, let's go ahead with it.

Let's take the Sun, which you'll remember is 864,000 miles in diameter and reduce it to a diameter of 500 feet. Four miles away let's put down a twenty-inch ball; that represents Mercury, the planet closest to the Sun. Three miles from Mercury, seven miles from the Sun, we have a four-foot sphere which represents Venus. Just a slightly larger sphere, ten miles from the Sun, is Earth. Mars is a slightly less than three-foot sphere fifteen miles from the Sun; Jupiter a forty-seven-foot sphere fifty miles from the Sun; Saturn is ninety-two miles from the Sun and is forty-two feet in diameter; two balls fifteen feet in diameter, and 180 miles and 290 miles distant would be Uranus and Neptune. Pluto would be 380 miles away from our 500-foot ball which represents the Sun. No one is quite sure how large Pluto is, but if it is as small as it seems to be, it would be represented by a sphere less than two feet in diameter.

And, in case you're curious about it, the nearest star would be slightly more than two and one-half million miles from the Sun—not in actuality, but on the representative scale used above.

All these figures, you must understand, are rough approximations, rounded out.

Or let's put it another way. Imagine a highway between the Earth and Sun. It is a good highway, so you can drive at a steady, 100-mile-an-hour clip. Driving night and day, not taking out a minute to eat or sleep, but driving all the time, it would take you almost 110 years to reach the Sun.

And if there were a highway from the Sun to Pluto, still driving at 100 miles an hour, night and day, never stopping, you would need 4,180 years to drive from the Sun to the outer reaches of the solar system.

You'd meet little along the way. The solar radiation close to the Sun would probably kill you if you actually were there; but this, after all, is a hypothetical trip.

From the Sun out to Pluto you'd be crossing the orbits of the other planets, but it would be improbable that you'd pass close to any of them. For space is big, and it is seldom that the planets line up with one another.

There'd be the planets, and occasional asteroids and meteorites, and maybe a wandering comet; and there'd be the solar wind blowing at your back.

The solar wind is the clouds of radiation and particles which come streaming out from the surface of the Sun, reaching deep into the solar system. There are particles and radiations racing out from the Sun continuously; but at certain times, when the Sun goes on a rampage of activity, they stream out in much thicker and more energetic clouds.

The average number of particles in space between the Sun and the Earth will run from 100 to 1,000 per cubic centimeter, depending upon the activity of the Sun and perhaps a number of other factors. A centimeter, you'll remember, is about two-fifths of an inch.

And while this concentration of 100 to 1,000 particles per

cubic centimeter is crowded when compared to the situation which must exist in the space between the stars, where the density is about ten particles per cubic centimeter, it still is a good vacuum so far as we human beings are concerned.

At sea level on Earth the concentration is 1,600,000,000,-000,000,000,000 particles (protons, neutrons, electrons) per cubic centimeter. Even at 600 miles above the surface of the Earth, where we can rather arbitrarily say the atmosphere ends and space begins, there still are 12,000,000 particles per cubic centimeter.

So you'd be traveling in what amounts to a much better vacuum than anything man has ever been able to achieve, despite all the tricky pumps he has in his laboratories.

While all indications for some time pointed to the existence of the so-called solar wind, on-the-spot evidence of it was obtained in the spring of 1961 by a space probe which was sent aloft from Cape Canaveral.

The experiment was conducted by Dr. Bruno Rossi, professor of physics at Massachusetts Institute of Technology. He installed a rotating cup on the surface of the probe. When the sun-driven particles streamed through the cup opening, they were converted into electrical signals which were automatically transmitted back to Earth.

Direction of the wind (showing that it did come from the Sun) was determined by observing the intervals during which the cup recorded the electrical signals. The particles could enter the cup's opening only when it faced the Sun. This produced a rhythmic signal which indicated that the particles were being caught only as the opening spun around to face the Sun.

The wind travels at the speed of millions of miles an hour. Ordinarily, it takes between one and two days for it to travel from the Sun to the Earth.

Suggestions have been made that the solar wind might

be harnessed to drive spacecraft, with huge sails spread to catch the wind. There is a good deal of doubt, however, that the idea would work out. More will have to be known about the character of the wind before an evaluation can be made.

Since the particles hurled out by the Sun are for the most part highly ionized, magnetic fields move along with the gas. It is believed, however, that in most cases these magnetic fields remain connected with the Sun—for all the world as if they had roots planted in the Sun. There will have to be more study of the situation before the entire picture comes clear.

There is one term which we have not used in telling the story of radiation and the solar wind. That word is "plasma," and it should be mentioned.

Plasma is actually ionized gas. But when the word is used, it is used in the context of a fourth state of matter. We have solids, liquids, and gases, which are three states of matter. Plasma is the fourth state, and probably, some people will tell you, the normal state of matter—since there is more of it, pound for pound, in the universe than anything else. It is gas which is at a very high temperature, with the result that the atomic structure has broken down and the basic particles which go to make up atoms are forced to stand alone.

Leaving out Pluto, about which little is known, there are two kinds of planets in the solar system. The terrestrial planets, Mercury, Venus, Earth and Mars, are small planets fashioned out of rock and metal. The planets beginning with Jupiter are the giant gas planets—much bigger than the terrestrial planets, and probably with no rock or metal, as such, in them. They appear to be great balls of gas, compressed and squeezed until most of the gas resembles nothing we have ever known. It is definitely a kind of matter that has gone over the hill into some other world which is hard to comprehend.

And now we have skipped very hastily over the formation of the solar system, the appearance of life in the solar system, the sort of engine that the solar system happens to be. Hastily, because a full-sized book could have been written about each phase of our survey.

Now the question arises: How long is this all going to last?

Well, so far as the planets themselves are concerned, a long, long time. So far as life on Earth or on any of the other planets is concerned, perhaps not more than another five billion years.

The answer lies with the Sun, which is the source of all life in the solar system—whether that life be on Earth alone or some of the other planets.

The Sun is a star; and stars, while they may seem eternal, are not. Stars definitely pass through various phases. What the fate of each star is to be is determined by its size and its type.

The Sun, thankfully, is a steady star. It goes about its business sedately; it is not addicted to acting up, as some stars are.

What the Sun does will follow the natural law which operates throughout the universe, and to which nothing, neither man nor star, can be immune.

In some five billion years, astronomers believe, the Sun will become unbalanced and will expand to something like thirty times its present diameter. As it expands, it will cool down; but even so, its great expansion will radiate more heat out into space. With the Sun's expansion, the temperature on Earth will increase to the neighborhood of 1,500° Fahrenheit. That will spell the end of most life. Bacteria buried deep in the rocks or in the soil might just possibly survive. Not much else would. Technically, life still might remain; but life as we think of it today would be impossible.

How long the Sun will remain at its expanded size is

problematical. The chances are that it will burn out the greater part of its hydrogen rather rapidly and then will collapse again and become what is known as a white dwarf. As a white dwarf it will be a great deal hotter than the Sun is today; but it will be so small, something like a thousand times smaller than it now is, that it will radiate little heat.

The Earth, cooling off, will freeze.

And the solar system then will be dead. It will remain for more billions of years. But nothing will happen, nothing will stir; there will be no life.

Thirty to fifty billions of years from now the last flame will flicker in the Sun. The atoms will cease their restless stirring. All will be quiet and cold and dark, for with the Sun gone there will be no heat and no light.

And the solar system, once so brave, once so fiery, once so proud, will go drifting down the ages like a train of ghosts, dead clinkers that have served the purpose for which they were formed.

And that purpose?

To serve as a cradle for us, for humanity?

We would like to think so.

But we can't be sure.

5.

The Bomb Up in the Sky

IN THE CENTER OF THE SOLAR SYSTEM WE HAVE A hydrogen bomb. If it were not for this bomb, no single one of us would be alive today.

Crazy, you say.

Not at all.

The Sun is in effect a hydrogen bomb which never quite explodes; always at the very verge of continuous explosion, but under perfect control.

The heat that warms you, whether from the rays of the Sun itself, or from the fuel which you may be burning, either in your body or your house, comes from nuclear reaction within the Sun.

The food you eat comes about as a result of nuclear reaction in the heart of a star ninety-three million miles away—the Sun. The very fact that you are here at all—that

anyone ever has been here—can be traced back to the Sun.

As a matter of fact, we even are directly connected with the Sun. For the Earth lies within the outer fringes of the solar atmosphere.

The Sun is the most important factor in the lives of all of us. It is the basis of all life in the solar system—not only here on Earth, but on any other planet where life may have arisen. We don't know if there is life on any of the other planets; but if there is, it owes as much to the Sun as we do.

Because of this it is important that we know as much as possible about the Sun.

And not only that: The Sun as well may hold secrets of energy production which can be adapted by man. We've already made a small step in this direction with our atomic power plants. In an atomic power plant we are imitating, on a small scale, something of what is happening inside the Sun.

Stars, apparently, are designed to be stable in their nuclear operation. If, from a study of the Sun, we could learn the secret of their stability, then man would be set for all of humanity's life so far as energy is concerned. He could, within his own man-made reactors, light the fires of hundreds of tiny suns; and power would pour out such as never has been dreamed of. Power then would be so plentiful and so cheap that man would never again need to worry about the availability or the cost of power for any task he might want to perform.

And furthermore, the Sun at this very moment is the source of a power which is there for the taking. All we have to do is figure out how we can capture it and use it. Very roughly calculated, the energy from the Sun represents about one horsepower for every square yard of surface upon which full sunlight falls. There are thousands of times more horsepower falling on the Earth in the shape of sunlight than we can ever think of using. The sunlight falling on 200 square

miles of Earth's surface would furnish, right now, all the power that we can use.

There are in operation several types of solar power plants—that is, plants powered by the Sun. But they all are inefficient. Work is going on at a number of places in an attempt to find more efficient ways in which sunlight can be used.

There is another reason also why scientists are interested in studying the Sun: The fact that it is a star, and a fairly normal star. It is the only star near enough for us to study in detail. Even the most powerful of our telescopes fail to make any other star, even the nearest of them, more than a single point of light. All that we learn from the other stars (and we learn a great deal from them) is learned by the use of very complicated instruments. But the Sun is close enough so that we can study it in great detail; and, bit by bit, we are digging out its secrets. By learning about the Sun, we learn about the other stars. And it is only from learning about stars that we gain an understanding of the universe.

But when we have said all this, when we have listed all the other reasons why the Sun may be important, we always come back to the matter of utmost importance to each of us personally: the fact that the Sun's energy is the basis of all life. And not only of life itself, but of everything that happens in the solar system.

It is the energy of the Sun that causes water to evaporate and to fall later as rain. It is the Sun that powers our atmosphere and gives us our weather and our climate. It is stored solar energy that we are using when we burn wood or coal or oil. Our food is based on the Sun's energy, absorbed by plants.

There is no work done anywhere on Earth or in the solar system which does not stem directly from the Sun. And by work we mean not only the work that a man may do, but that wind or weather or water or anything else may do.

The Sun is ninety-three million miles distant from the Earth. Two Russian scientists, Vladimir Kotelnikov and Josif Shklovsky, measuring the distance by means of radio signals, in May of 1961 gave the figure as 92,812,797 miles, give or take 5,000 miles. The World Almanac lists the distance at 92,839,000 miles. But for the purposes of this book, and for almost any purpose, ninety-three million is a good round figure, and we'll use it.

As near as can be figured, the Sun's diameter is 865,370 miles. It has a mass of 2.2×10^{27} tons, which is 22 followed by 26 zeroes—333,434 times more massive than the Earth. You can squeeze over a million Earths into the space it occupies. Its light requires eight minutes to reach the Earth. Its surface gravity is twenty-eight times that of Earth.

A huge ball of gas held together by its own gravity, the Sun is composed of about 70 percent hydrogen, the ultimate nuclear fuel. Eight hundred million tons of hydrogen are being converted into helium every second within this great heat engine. In the fiery atomic cycle a good part of the hydrogen is recovered, but not all of it. Four million tons of the Sun's mass is radiated away in the form of energy every second.

The process by which the Sun produces its energy (which comes out in various forms: light, heat, gamma rays, ultra-violet rays and others) is called atomic fusion. In atomic fusion very light atomic nuclei, usually hydrogen, combine to form a heavier nucleus, usually helium. But in this fusing to form a new and heavier nucleus, some of the mass is lost. Since the bookkeeping of Nature is a strict and exact bookkeeping, nothing can be lost, everything must be accounted for. So this loss in nuclear mass comes out as a gain in energy. The mass which has been lost is accounted for by the release of energy.

The system by which the nuclear process operates in the Sun is known as the proton-proton reaction.

The basic reaction is not too involved, but several steps are required. So we'll take it slowly.

First, two protons combine. Protons, as you'll recall, carry positive charges. But when the two protons combine, a positively charged electron emerges from the combination, leaving one still positively charged proton and the other without any charge—in other words, a neutron.

A proton and a neutron form what is known as deuterium, or heavy hydrogen. The nucleus of this atom is called a deuteron.

Now along comes another proton and combines with the deuteron and we have helium. But no ordinary helium, which would have a mass of 4. This is helium-3, a light form of helium. In the process of this combination to form helium-3, there is a release of energy in the form of a gamma ray.

The next step is for two helium-3 nuclei to get together to make helium-4, which is ordinary helium. But in the process, an alpha particle and two protons are ejected, giving rise to more energy.

It all sounds singularly unexciting and unimportant, but it proceeds within the Sun, uncounted billions of times each second, to produce all the energy which the Sun pours out.

Energy also could be produced by another and somewhat more complicated process called the carbon cycle. For some time it was believed that the carbon cycle was going on within the Sun; but the weight of evidence now seems to be that most of the energy is produced by the proton-proton reaction.

It is just possible that both reactions, the carbon and the proton-proton, are going on at the same time. At thirty million degrees Centigrade, the carbon chain would have to be the process by which energy was manufactured, since

temperature is a controlling factor in determining which process would be in operation. At ten million degrees, the proton-proton chain would be operative. The Sun's interior temperature is in the neighborhood of fifteen million degrees. Whether this is too low a temperature to allow the carbon cycle to operate is not known. It may be, and the best guess is that most of the Sun's energy is brought about by the proton cycle, with a possibility that the carbon cycle may be taking place to a lesser degree.

The energy which is being manufactured in the Sun originates in its deep interior and is equal to a billion H-bombs exploding every second. But this energy, created within the heart of the Sun, takes some millions of years, at a comparative snail's pace to work itself up to the solar surface.

This is because the atomic particles, under the great pressures which exist deep inside the Sun, are packed so tightly that a package of energy can move only the slightest fraction of an inch before it bangs into something else. And a small fraction of a second later into something else. And so on—fighting and squirming its way up toward the surface. Like a rat running in a maze, the radiation trickles slowly upward, bounced and jostled, but moving just a bit more easily all the time as the pressure wears off and the Sun's material becomes fractionally less dense.

Thus, the sunlight which fell upon us today represents energy which was manufactured, deep in the solar heart, before there was anything like man walking on the Earth.

The density at the core of the Sun probably is equal to about a billion times the pressure of the atmosphere in which we live. Here we have a condition very like that we were describing as existing in the primeval mass from which it is supposed the universe might have been created—except that the Sun's core is nowhere near as dense as was that primeval mass. The particles which form the core of the Sun still have

space in which to move about and to combine, in order to effect the release of energy.

The thing which must be borne in mind is that the Sun is in no sense solid. It is a gas throughout, or, perhaps, more correctly, a plasma. For by and large we are not dealing here with an atomic structure, but with atomic particles which have been broken down into their component parts—the subatomic particles.

When we talk about the surface of the Sun we are talking about something which actually does not exist in the sense that we usually think of a surface. The Sun is gas all the way through—essentially an atmosphere all the way through, but fantastically dense at the center.

We do see what is an apparent surface. This is what is called the photosphere, the point beyond which we cannot see deeper into the Sun. At this point, the gas is not nearly so dense as it is at the core—in fact, it is far less dense than the atmosphere in which we live. It is probably about as dense as our atmosphere is fifty miles above the surface of the Earth. The temperature of the photosphere is in the neighborhood of 10,000° Fahrenheit.

Between the photosphere and the chromosphere, which is the next outward zone of the Sun, is a shallow area, probably not more than 600 miles deep, which is known as the reversing layer. It is relatively cooler than either the photosphere or the chromosphere, although by human standards it is still terribly hot.

The chromosphere extends out into space for about 6,000 miles. It is a constantly seething mass of gases. Its temperature is somewhat greater than that of the photosphere.

At the outer edge of the chromosphere the density of the Sun's gas has thinned out to a point where it becomes a fairly good vacuum—6,000 particles per cubic centimeter. But the corona, which stretches for millions of miles into

space, is hot. Its temperature probably reaches more than a million degrees.

But here we must make a distinction. There is a difference between temperature and heat. When we speak of heat we are talking about the total energy contained in the motions of particles in a given quantity of matter. Temperature, however, represents the average speed of particles in motion. In the corona of the Sun the temperature of the particles is high, but there are so few of them that there is, relatively, only a little heat involved. In the denser portions of the Sun, where the matter is closer together, high temperatures spell tremendous heat. But in the tenuous gases of the corona, while the speed of the particles are high, they spell but little heat.

The Sun, as we noted earlier, is a ball of gas which could be called, without stretching truth too far, a mass of atmosphere.

And since this is so, the question arises: How big is the Sun? How far does it reach out? Where does it finally come to an end?

In actuality, the Sun can be said to end only at the point at which the density of its gases has fallen to the level of the density of the gas in the space between the stars.

Dr. Sydney Chapman, a British scientist who for the past several years has been connected with American universities, was the first man to advance the idea that the Sun may extend beyond the Earth—that the Earth, in fact, may lie in the outer reaches of the Sun.

Chapman was not talking about the proton storms which result from disturbances on the Sun, but about the every day condition. Even when the Sun is quiet, the particle count stemming from the Sun is high enough, in the vicinity of the Earth, to qualify as a detectable density of solar material. The chances are that the Sun's atmosphere does not actually come to an end short of the vicinity of Mars.

The Sun is a restless thing. Its surface is continually in motion. And its interior is in motion as well, more than likely, although we cannot see, but must only guess at, the conditions which are found there.

When looked at through a telescope, the Sun has a granular appearance. This granular appearance has at times been called the "rice grain" structure. Others have likened the granules to cobblestones, as if the Sun were paved.

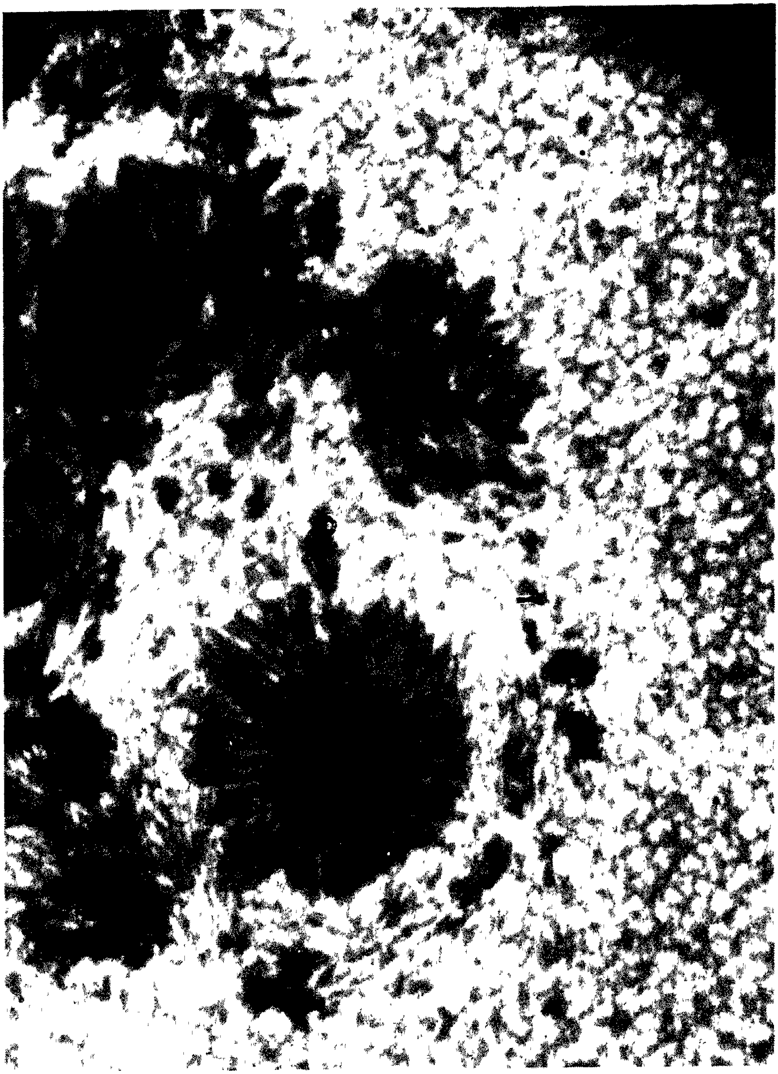
The individual granules measure from 375 to 950 miles across and are continually dissolving and reforming. It is believed that the granules are what may be called convection cells. They may be formed by hot, ionized gas rising to the surface of the photosphere. Since the convection cell is hotter than the photosphere, it may rise higher into the solar atmosphere and finally be torn apart by the solar winds which blow at something close to a thousand miles an hour.

The solar feature, however, with which most people are acquainted are the sunspots.

Sunspots were known to man for many years before there were instruments with which to study them. Some of the larger spots are visible to the naked eye, especially if one is looking at the Sun when it is dimmed, at the time of rising or setting, by haze near the horizon.

Sunspots, appearing as dark blotches on the photosphere, are enormous structures. Even the more insignificant of them would swallow the Earth without any difficulty. The largest one recorded had a diameter of 40,000 miles.

The spots seem to be dark only because they are cooler than the surrounding surface of the Sun. Sunspot temperatures run around 7,500° Fahrenheit, as compared with 10,000° for the photosphere itself. As a rule, the spots have a darker inner portion which is called the umbra, surrounded by the penumbra, which is brighter than the umbra, but still darker than the solar surface. In appearance the spots somewhat resemble whirlpools.



Photograph of active sunspot group taken from a balloon. Note the rice-grain structure of the Sun's surface and the darkness of the lower-temperature sunspots. (Project Stratoscope of Princeton University, sponsored by ONR, NSF and NASA)

The spots have a habit of appearing in groups. At times the spots are of about the same size, but at other times one large spot will be associated with smaller spots.

The smaller spots last for only a few days. Larger ones may survive for several weeks. There is a record of one huge spot which hung on for eighteen months, but this is exceptional.

It was the spots which revealed to us the rotation of the Sun, and supplied simple data for the measurement of the speed of the rotation. Since the spots ride along on the surface of the photosphere, all you have to do to measure the speed of rotation is to time a spot through one full rotation of the solar surface.

There is a funny thing about the rotation of the Sun. Unlike the Earth, the Sun does not rotate at the same rate in all its zones. The period of rotation at the equator is twenty-five days, three hours, twenty-two minutes. But at 40 degrees latitude, north or south, the rotation period is twenty-seven and a half days, while at 75 degrees latitude, the period is slightly more than thirty-three days.

This, if nothing else, should tell us that the Sun is not a solid, as is the Earth. A solid sphere would have the same rotational period at all points, although, because of its spherical shape, the speed of rotation would vary at different latitudes. In a gas or liquid body a condition such as we find in the Sun could exist.

It is known that the sunspots form within magnetic fields on the surface of the Sun. It appears that the field forms before the spot appears, and that in many cases it remains after the spot has vanished. It is likely that the same magnetic field may give birth to a series of spots. There is some indication that a sunspot may be, actually, a magnetic storm.

It is believed that the varying rates of rotation found in the Sun may have something to do with the Sun's magnetism.

The Earth's magnetic field, except under certain well-defined conditions, remains fairly stable. It shifts around so that the magnetic poles change from century to century; but the change is slow. In the Sun, with the equator rotating more swiftly than the rest of the sphere, the lines of force may be twisted out of shape. There is a possibility, too, that there may be local as well as general differences in the Sun's rate of rotation, and that these differences create new twistings in the local magnetic fields.

It is apparent that a number of magnetic fields may exist over the surface of the Sun.

Whether or not the Sun has a general magnetic field as well is something that is as yet not entirely settled. Recent observations seem to indicate that it has.

Experiments performed by Dr. Horace Babcock, a Mount Wilson astronomer, indicate that the Sun does have a general field, but loses it at "sunspot maximum." Sunspot maximum is that period during which the Sun has many spots; sunspot minimum is that period during which it has only a few. We'll get into the matter of the sunspot cycle in just a while.

Babcock's observations indicate that when the Sun has lost its magnetic field, regained it and started building it up again, it has reversed its polarity.

Another observation which strongly supports the belief that the Sun does have a general magnetic field was made in the fall of 1959 by Dr. Edward P. Ney and a team of University of Minnesota physicists.

Traveling to the Sahara desert to observe an eclipse of the Sun, Ney hoped to find support for a theory that the Sun has a "Van Allen belt." The theory had been developed by Ney and Dr. Paul Kellogg, also of Minnesota.

Ney found evidence, but not the absolute proof that he needed to be certain, that the belt does exist. But as a result

of Ney's data, the case for a general field for the Sun is much stronger than it was before.

Because if the belt exists, the general field also must exist. You will recall that the Earth's Van Allen belt is within the Earth's magnetic lines of force, and that without the lines of force there would be nothing to hold the belt in shape.

Ney's data showed that while the light of the corona as a whole appeared to be circular, the profile as shown in polarized light assumed the curiously lopsided effect which is shown in Earth's radiation belt. (An explanation of this would have to take us into a complicated exploration of polarized light and what it has to do with the Sun's corona; it simply cannot be explained in anything approaching easy terms. Besides, it would lead us far afield.)

But Ney did note something else which supports his theory that the Sun has a radiation belt; and this can be explained without too much trouble.

He found that no electrons existed in the corona of the Sun from the poles down about 20 degrees across the surface. In other words, from 70 degrees north and 70 degrees south, up to the poles, no electrons were detectable.

This, Ney explains, is exactly what would be expected if a radiation belt were present. The belt would have trapped all the electrons hurled out by the Sun. And, if you'll recall, the Earth's radiation belt curves in at the poles, forming the "hole in the doughnut."

Considering only the content of the radiation belt and not the atoms and the molecules of Earth's atmosphere, this is the situation which must exist on Earth—no electrons in the polar regions, since the belt stops short of the top and the bottom of the planet.

Ney's observations were taken about two years after the Sun had reached one of its sunspot peaks. He believes that

later in the period of more quiet solar activity, when the field had become more firmly established, the profile of a radiation belt would be even more pronounced.

The sunspots run in cycles of about eleven years. That is, every eleven years, spots are at a minimum. At times there are only a few spots. At other times days may pass without a spot showing up. But in between these eleven-year periods the spots will rise to a maximum, with the Sun at times looking almost as if it had a case of smallpox.

While the cycle averages out to roughly eleven years, it does vary. There have been some cycles as long as sixteen years, some as short as seven and a half. The last sunspot maximum was reached in 1957. There also is considerable fluctuation in the intensity of the maximum periods. Some of them are highly active, others are quieter.

There is no explanation of the cycles.

There was a time when it was popular to blame many different occurrences on the sunspots. It was during periods of high sunspot activity, it was said, that wars broke out, that wheat prices were high, that the stock markets went well.

There is a possibility that there may be some truth to this, although the data is so fragmentary that no good case can be made of it.

But there is one well-documented relation between the spots and happenings on the Earth.

You probably are aware that the trunk of a tree shows a series of rings. Each ring represents one year of growth. A thick ring means that the tree made good growth in that particular year; a thin ring means that it made little growth.

A study of tree rings has shown that the thickest rings, representing the years of greatest growth, coincide with the years when sunspots were at their maximum. The reason probably is that the sunspots affect our weather here on Earth, with the result that warmer weather and more rain

(good growing weather) comes in those years when the sunspots are at their height.

Sunspots run in definite patterns, as well as in cycles.

At the beginning of an active sunspot cycle, the spots appear at a latitude of about 25 or 30 degrees, north and south. As the cycle progresses, each new batch of spots appears at a slightly lower latitude, each new group nearer the equator. When the final batch of spots appear they are within about 5 degrees of the equator.

As the last of the first cycle of spots fade out near the equator, the first spots of another cycle of high activity may be beginning to form in the higher latitudes.

The spots, however, are not the only example of violent activity on the surface of the Sun.

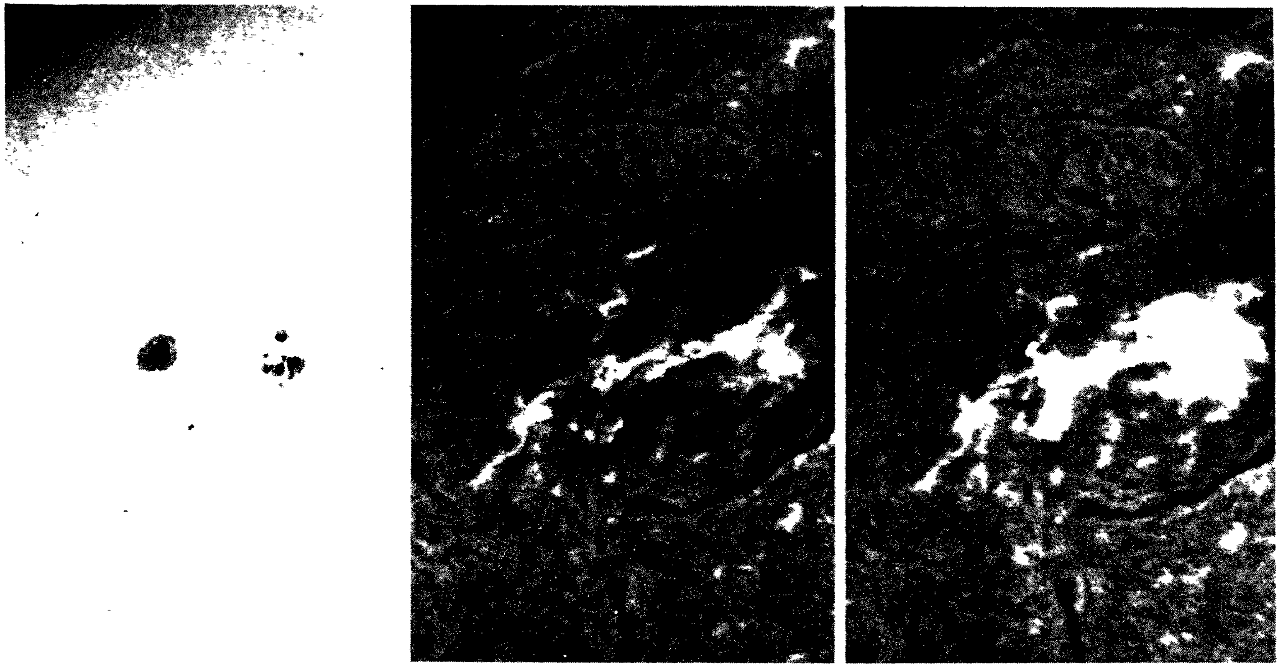
Another feature are the faculae, which appear to be clouds, and actually may be clouds of gaseous calcium. These clouds are always found near sunspots, and at times hover over the spots. It is believed that the faculae may be gas clouds brought to white heat by twisting magnetic fields. They have come to be regarded as indicators of the intensity of solar disturbances. The brighter they are, the more violent are the activities on the nearby photosphere.

A third type of disturbances are the flares, which appear in the chromosphere, above the photosphere, which we think of as the surface of the Sun.

The flares flash out suddenly, ten times brighter than the brilliance of the Sun. They come in all sizes, from the small ones, which would cover half the area of Earth, to the large ones which may cover a billion square miles. They ordinarily occur in the vicinity of sunspots, and as many as a hundred may appear during the course of one day.

The smaller ones may last for no more than fifteen minutes, while the larger ones may remain for several hours.

It is the solar flares that send out the proton storms which bombard Earth and which may make space travel



These three photographs show the development of a solar flare. Note that in slightly more than a quarter of an hour the flare had reached its maximum brightness. (Mount Wilson and Palomar Observatories)

hazardous. Some flares cause proton storms. Others do not. So far, physicists have no clue as to why this is so.

But each flare does send out into space a wave of ultraviolet.

The radiations thrown out by the flares produce weird effects on Earth. They distort the magnetic lines of force surrounding Earth, and, by this distortion, dump particles out of the Van Allen belt. The particles being dumped out of the belt produce the northern lights, which flash out and waver in great streamers across the northern sky.

The radiations from the bigger flares twist out of shape that part of Earth's atmosphere which acts as a mirror in bouncing radio waves back to the surface. As a result, radios black out. During the time of a big flare, radio transmission over a good part of the world may be knocked out.

The flares are generally believed to be an excitation of great areas of gas in the chromosphere. This excitation probably is caused by some sort of radiation originating in the photosphere.

Because of the suddenness with which the flares break out, they have been compared to lightning flashes. At one time it was believed that a flare might be exactly that—a lightning flash caused by the buildup of vast electrical potential in the Sun. Now this is thought to be unlikely. It is believed now that the Sun's chromosphere is a much better conductor of electricity than the Earth's atmosphere. In a good conducting medium, no electrical potential can build up. The electricity, instead of being trapped, flows. So, in all probability, massive currents of electricity may be flowing through the chromosphere. Under these conditions, lightning would rarely, if ever, happen.

Our own Sun is not the only place where flares occur. In a few instances, flares have been detected on other stars. Not that anyone has ever seen these flares. But sensitive

A solar prominence flares 140,000 miles above the surface of the Sun.
(Mount Wilson and Palomar Obseratories)

instruments used by astronomers have shown a sudden, short-lived increase in the brightness of some stars. This momentary brilliance is believed to have been caused by giant flares.

Still another form of disturbance on the Sun are the prominences. These are huge streamers of particles and gas thrown out from the surface, some of them reaching out as far as 100,000 miles. They are longer-lived than the flares, and seem to be anchored in the photosphere, almost as if they had roots thrust into the surface. The prominences at times are called filaments.

As with the flares and the faculae, the prominences generally are associated with sunspots.

While some prominences may last for months, others fail to form fully and may last only a week or so. While they may reach out as far as 100,000 miles into space, they may be five times as long overall, since they seldom extend straight out but tend to form loops, curving up in a long arc and then looping back toward the surface.

Perhaps you have noticed that all of the disturbances on the Sun are associated with sunspots. It is almost certain, however, that it is not the spots which cause them. Rather all of the activity, including the spots, arises from causes which originate deep within the Sun, down in that area where we cannot pry.

There is one other phenomenon—radio waves— connected with these centers of disturbance. Radio telescopes pointed at the Sun pick up a steady hum originating in the area of the spots. The hum is caused by waves of higher than 30,000 megacycles.

In addition to the steady hum there are three other types of signals which come in bursts. One, caused by waves of about thirty megacycles, lasts for about two minutes per burst and may continue for hours. Another, of a slightly higher frequency, lasts about ten minutes. The third consists

of isolated and infrequent bursts of signals of about 30,000 megacycles.

Just how these waves are formed or what they mean no one as yet knows. But again, the Sun is not alone in its broadcasting. Other stars broadcast radio waves as well.

One of the most spectacular and awe-inspiring sights on Earth is a total eclipse of the Sun. An eclipse is caused when the Moon, in the course of its rotation about the Earth, moves between the Sun and Earth, blotting out the Sun. A total eclipse is seen from only a very small section of the Earth. In other nearby places, the eclipse appears only as a partial eclipse; that is, the Moon covers only a portion of the Sun. In still other parts of the world, because of the angle from which one looks at the Sun, no eclipse is apparent.

A good many people have never seen a total eclipse. I have seen one in my lifetime and never shall forget it.

I was not, to start with, excited about it. I had seen total eclipses of the Moon and these had been only a matter of mild curiosity. I made the mistake of thinking the two would be similar. I knew it was a historic occasion and that a number of prominent scientists had come to our city to study it. But as something to see, I discounted it.

As I got out the car that morning to drive to work, I noticed that the Moon had started to take its first bite from the Sun. Groups of people stood along the highway, watching the eclipse as it progressed. I watched it, too, not too greatly stirred.

The light began to dim, a strange quiet seemed to fall, and I began to realize just how wrong I'd been. Here was not just something to watch; here was an experience. Here was truly the greatest show on Earth, the most impressive thing I had ever seen. I pulled the car off on the shoulder of the highway and got out. There was just a slice of the Sun left and suddenly it, too, was gone. The world was in

deep twilight. Startled birds were flying wildly, chirping and crying in bewilderment. The twilight had an eerie feel about it, and it seemed to me I could feel a sudden chill. Up in the sky the corona was a faint halo around the darkened circle where the Sun had been blotted out. And there was a queer unnaturalness about it—as if one stood in shivering wonder in the most beautiful and awe-inspiring church in all the world, a church that no hand of man ever could have built.

So long as I live I never shall forget it.

I realized as I stood there, struck absolutely speechless by the beauty and the majesty of it, how our remote ancestors could have been frightened by an eclipse. Had I not known the reason for it, I'd have been frightened, too.

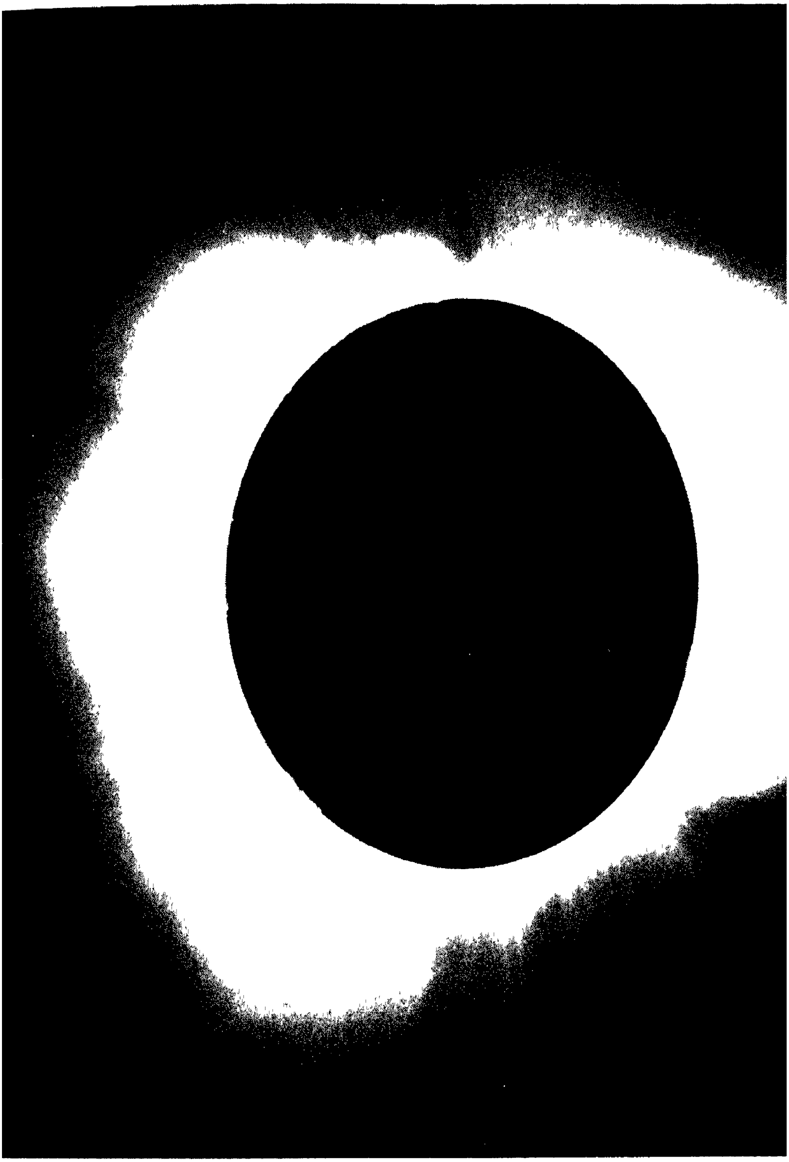
There are certain things to look for when you're viewing an eclipse.

Just at the moment before totality, and at the moment after, you can see the Bailey's Beads. The light of the Sun, shining through the notches in the mountains on the Moon, appears as dazzling spots of light around the darkened disc. They are there for but a second, then are gone.

The corona, which ordinarily is hidden from human sight by the brightness of the photosphere, glows in the darkened sky. With field glasses you can glimpse red jets flaring out beyond the edge of darkness. These are the prominences arcing out thousands of miles beyond the photosphere.

And if you're very lucky and watch closely enough you'll see the so-called "diamond ring." It comes just as the Sun begins to emerge from behind the Moon—with the first speck of the Sun flaring into brilliance as the "diamond," and the glow of the inner corona as the "ring."

Except for the corona, I don't recall that I saw any of these things. I was so stunned and startled, so absorbed in the general aspect, that I'm not sure I looked for anything specifically.



The Sun's corona as photographed during a total eclipse. (Mount Wilson and Palomar Observatories)

At one time, astronomers and other scientists who wished to study the corona and the prominences had to wait for eclipses to blot out the brilliance of the Sun itself. But now, with the invention of the coronagraph in 1930, scientists can create artificial eclipses, so far as their instruments are concerned.

Unless you're able and willing to travel, you may never see a total eclipse of the Sun. Although one occurs about every eighteen months, it is only on an average of once in every 360 years that an eclipse can be seen from any one particular area on the Earth. During this century only twelve total eclipses have been visible in some part of the United States. The next one will be in 1963, on July 20—visible in Maine. On March 7, 1970, another will be visible along the eastern coast, from Florida to North Carolina.

The Sun is regarded as a stable star—one about which we do not immediately need to worry that it will run wild. But it may be that it does have cycles during which it is either hotter or cooler. We do know that in the next several billion years it will heat up tremendously and wipe out all life that remains upon the Earth at that time. But aside from that, there appears some evidence that it may fluctuate, to a much lesser degree, as a regular procedure.

A study of the Earth shows that in ages past the climate of our world has varied rather widely. During the last 500 million years Earth has experienced three ice ages: the Eocambrian, which started about 480 million years ago; the Permo-Carboniferous, which began 230 million years ago; and the Quartenary, which started a few million years ago. We still are in the Quartenary ice age. But ice ages themselves have their glacial periods, when great ice sheets creep across the land, and their interglacial periods, when the weather warms and the glaciers retreat. We are now in the beginning of

an interglacial period. The glaciers of the latest phase of the Quartenary ice age began to retreat about ten thousand years ago. The present ice age probably will continue for another fifteen or twenty million years.

The present average temperature of our planet is 58° Fahrenheit. At the time of the greatest glacial period, at the depth of an ice age, the average temperature may have been no higher than 40°. During the height of an interglacial period, it may be as high as 72°. When that happens in our interglacial period (if something doesn't change and prevent its happening), the ice will be gone entirely from both the Arctic and Antarctic, and Greenland and other cold spots of today will enjoy balmy weather.

Because of the water released by the melting of the ice locked in the glaciers of the world, the ocean level will rise some 220 feet. New York and Washington and much of the eastern seaboard of the United States will be under water. The Gulf of Mexico will extend to the vicinity of St. Louis.

Actually, however, there will be little, if any, loss of land surface. Greenland and Antarctica, with the ice gone, will become living space—and will be even larger than they are today. Because when the ice is gone, new land will rise in the areas now covered by ice—for land masses, like ice masses, sink as they become heavier.

When you see an iceberg, you see only one-ninth of it. The other eight-ninths of it is beneath the water. In the case of land masses (that is, the crust of the Earth) only about one-sixth is above the surface of the Earth, the rest being sunk into Earth's mantle.

Put an additional weight of millions of tons of ice on top if it, and it sinks even lower. In Greenland and Antarctica there are land masses which have been pushed below sea level by the weight of the ice upon them. Take off that

ice load and the land mass will bob back up again, just as a cake of ice will rise if you are riding on it and suddenly jump off.

Today there are sections of Canada, Finland, and Russia which at one time, during the last glacial period, were pushed below sea level by the weight of the ice on them. The land level in these areas still is rising today—so slowly you'd never notice it, but rising just the same.

Whether the changes in Earth's climate are due to the alternate dimming and brightening of the Sun, no one can be sure. There are a number of other situations which could bring the changes about.

But the point we'd like to make is that while we're not sure fluctuation in the Sun is the cause, it very well could be. Which emphasizes once again how dependent we and all other life on Earth are upon the Sun.

Should the Sun's warmth drop off by only a few degrees, or rise by only a few degrees, our lives would be deeply affected. We live by virtue of the Sun's energy; we survive on sufferance of the Sun's behavior.

And as well as being a life-giver, the Sun also is a teacher. We are learning many things by our study of the Sun. We found helium in the Sun before we found it on the Earth. We may some day in the future learn from the Sun the secret of its production of energy. By studying the Sun we learn about the stars. And there undoubtedly are many other secrets there for us to learn, if we can only probe them out.

6.

The Moon: A Stepping Stone

WHEN MAN LEAVES EARTH AND HEADS OUT INTO space, his first destination will be the Moon. It is our nearest neighbor, a mere quarter-million miles away. This is only a tiny step in comparison with other distances in our solar system.

But aside from its nearness to us, there are three other good reasons for making the Moon our first stopping place: First, because it will serve as a stepping stone to the other planets; second, because by building an astronomical observatory on the Moon, man will be able to expand his knowledge of the universe, perhaps many-fold; and third, because by a study of the Moon man most certainly will be able to learn much about the Earth.

Let's take up these three reasons in order.

Because of its low gravity, the Moon would serve admir-

ably as a way station into space. When we have space travel on something like a business basis, it is probable that the Moon will be the Earth's spaceport.

What makes it so difficult for us to get a spaceship off the Earth is that we must fight Earth's gravity. No one knows what gravity is. But however it may work, it is the force which attracts everything toward the surface of a mass—in our case, toward the Earth. When you fall off a fence, it is gravity that makes you fall; it pulls you down to the surface of the Earth. If there were no gravity, you could throw a ball into the air and instead of its falling back, it would keep on going, up into the sky and out of sight. And what is more, you yourself would have nothing to hold you to the Earth, and would be liable to go flying off almost anywhere at almost any time.

The force of gravity works against us when we try to send a ship into outer space. We have to have the power to keep it going until it gets beyond the clutches of Earth's gravity. When we shoot for the Moon, our ship will travel out against Earth's gravity until it reaches the point at which the Moon's gravity is greater than the Earth's. Then the ship will fall toward the Moon. Which means that it will have to use more power to brake its fall, so that it doesn't crash into the Moon under the full pull of its gravity.

Because the Moon's gravity is only one-sixth that of Earth, it would be easier for a ship to lift off the Moon and head out into space from there. This means that we would need less fuel to get a certain number of tons off the Moon than we would to get them off the Earth. And this means, in turn, that we could use bigger ships and carry heavier cargo.

It is possible to speculate that the far-traveling ships which will one day go out to the other planets will wait on the Moon while smaller shuttle ships bring up from Earth

the fuel, the cargo and the passengers scheduled for a trip. Once loaded, the big Moon ships will take off with the expenditure of only a fraction of the fuel that would be needed to lift the same load off the Earth.

The big ships used on the Moon probably would be assembled there or in space itself from prefabricated materials shipped up from Earth section by section.

So far as the building of an astronomical observatory on the Moon is concerned, there are two schools of thought. Some astronomers argue that an observatory located in a space station—a large satellite, orbiting high above Earth's atmosphere—would serve as well as an observatory on the Moon. Others are convinced, however, that there is a good deal to be said for having a telescope anchored on solid ground.

At the present moment, astronomers operate under severe limitations. No matter how carefully they choose locations for their telescopes, their work is hampered by Earth's atmosphere. There are nights when they have no "seeing" at all because of cloud cover. Even on the best of nights, the atmosphere is disturbed by air currents. It is the air current movements which cause the stars to twinkle. Out in space the stars would have no twinkle. They'd be bright points of light. Even on the quietest nights, the image of a star or planet quivers and wavers in the telescope.

Aside from this wavering, the penetrating power of telescopes on Earth is cut down by what is known as "sky fog." Sky fog apparently originates with the scattering of starlight by the atmosphere, although the light emitted by the atoms in the air itself may contribute to it. Out in space (and for all practical purposes, the Moon is in space), there'd be no scattering of starlight since there'd be no atmosphere to scatter it. And there'd be very few atoms to emit light.

Another advantage of a telescope in space or on the Moon is that the sky would be black—utterly black—and

would provide a greater contrast for the viewing of the stars or planets.

Still another point: In space or on the Moon, telescopes would be able to pick up all the light traveling from the stars. On Earth we receive only about 70 percent of the light, the other 30 percent being screened out by the atmosphere. Screened out almost entirely is the ultra-violet light. Ultra-violet can't be seen by the human eye, but can be photographed. A study of the ultra-violet light broadcast by the stars would tell us much about their makeup.

You can't say absolutely that the Moon has no atmosphere, for as soon as you do, someone is certain to rise in the back of the hall and tell you you're dead wrong—that the Moon does have an atmosphere, but it is only one billionth or so as dense as Earth's.

It is possible that there are a few more atoms around the Moon than there are in space itself—no one knows for sure. But if there are, there are not too many more. Space six inches off the surface of the Moon is a far better vacuum than man ever has been able to obtain in his laboratories. For the purpose of telescopic observation, there is no atmosphere.

Since the Moon has no atmosphere, astronomers working there would have none of the headaches imposed upon them by Earth's atmosphere. There'd never be any clouds, there'd be no sky fog, there'd be no air current—for there isn't any air.

And another thing: On Earth, observatories (except for solar observatories, which study the Sun) are effective only at night. On the Moon they could be used twenty-four hours a day. The seeing would be a little better during the two-week night, only a little less good during the two-week day. For even with the Sun shining overhead, the sky still would be black and the stars would shine.

During the day, of course, the Sun itself could be studied

to a much better advantage than from Earth. Without the screening and the scattering of light by an atmosphere, and against a dead black sky, the corona would be visible and one could spot the flaming prominences that run along the rim.

And if some homesick astronomer should train the lenses of his telescope on Earth, he'd be able to see cities and the pattern formed by agricultural areas. He probably would be able to spot some of our great turnpikes as thin streaks running across the land.

But while there would be all these advantages to an observatory on the Moon, there'd be disadvantages as well.

For one thing, the observatory and its telescope would be exposed to the rain of meteorites which continually fall upon the Moon. On Earth, few meteorites ever reach the surface; most of them are burned up by friction with the air before they ever reach the ground.

Another disadvantage would be the great range of temperature on the Moon. During the day the temperature would rise to 214° Fahrenheit; during the night it would fall as low as 243° below zero. This is a range of 457 degrees, greater than anything we can imagine on the Earth.

Such a great range in temperature would wreck the lenses of a telescope, would warp the metal of the control mechanism.

But the dangers of both the meteorites and the temperature range could be minimized by locating the observatory at the bottom of some great crater, surrounded by high mountains. Shielded from the Sun, the temperature at the bottom of the crater would remain nearly constant—very, very cold. At midday on the Moon, the temperature in the full glare of the Sun is above the boiling point of water. But step out of the sunlight and into shadow and the temperature is far below freezing. There is nothing to carry the heat, nothing to spread or dissipate it.

Locating an observatory at the bottom of a crater would mean that it would be exposed continually to the bitter cold. This means that the materials used to construct the observatory and the telescope would have to be designed to withstand such temperatures.

The high walls surrounding the crater would give a large measure of protection against meteorites, although not complete protection. There'd always be the chance that the lenses might be smashed by a whizzing piece of stone or metal.

There is no positive knowledge of how many meteorites fall on the Moon. The best guess is that a million fall every twenty-four hours. The greater part of these meteorites probably are no bigger than a grain of sand, but they come in at an average speed of forty miles a second. Even a grain of sand packs a lot of energy at that sort of speed—perhaps enough to pit a lens badly if it should strike one.

The Moon's surface area is about equal to the size of the continental United States and Canada. Thus, while it must be realized that danger from meteorites exists, the meteorites actually are spread rather thin. There is always the danger that a big one, barn size or larger, might come crashing in; but that danger exists on the Earth as well as on the Moon. The chance that a really big meteorite will strike any particular area on the Moon is one in many million.

To get full sky coverage, two observatories should be built on the Moon: one at the south pole, another at the north. There are a number of deep craters near the south pole which would be ideal locations. But at the north pole the the craters are somewhat shallower.

Our third reason for going to the Moon—to learn more about the Earth by studying the Moon—may sound like just another system of doing things the hard way. The Earth is here at hand, you say; why go a quarter of a million miles out in space to study it?

Well, that is true, of course. But it means only that we can study the Earth as it is now. Any study we may want to make of the past history of the Earth requires a lot of digging. For the Earth has changed through the ages. At one time, perhaps, the Earth was as pockmarked with craters as the Moon. But on Earth today only a few of these craters can be found. The others have been destroyed by erosion due to wind and rain and other weather.

But it is not primarily the craters in which we are interested.

The Earth developed life and an atmosphere. The Moon, apparently, did not. This is a broad statement, of course, and is open to dispute. There are theories, not too generally accepted, that the Moon at one time had life, water and an atmosphere. But the general belief is that if the Moon ever had an atmosphere it lost it at an early period in its history.

Whatever the situation may have been in the past, the Moon for several billion years has been virtually a dead body. There has been little change on the Moon. It is almost exactly as it was some five billion years ago.

Since it is, except for one thing, the same kind of body as the Earth, scientists hope, by studying it, to arrive at some further understanding of how the Earth was formed and what it might have been like before atmosphere and weather and other forces set about making changes in it.

The one way in which the Moon differs basically from Earth is in its density. Earth's density is 5.52 times that of water, while the Moon's density is 3.33 times the density of water. The Moon must either be made of lighter materials, or else lack the Earth's dense central core.

Any material which is on the Moon is primitive and basic material. There are no sedimentary rocks, such as there are on Earth. Sedimentary rock is rock which was formed from sediment washed into deposits. Since there is no sur-

face water and little weathering on the Moon, there'd be no sediment—thus no sedimentary rock. (We say "little weathering" because there is *some* weathering. We'll get around to that a little further on.)

Actually, because it is so near and has been studied for so long and by so many people, we know a good deal about the Moon. Which doesn't mean, of course, that we understand everything we know. You can stir up more argument about the Moon than about any other body in the solar system, with the possible exception of Mars. And these differences of opinion revolve about almost every known feature of the Moon.

We know more about the Moon, for example, than we know about the floors of our oceans here on Earth. And yet, even by means of study from the Earth, there still is a great deal we can learn about the Moon. Until we finally reach the Moon, there is every reason for continued observation of it from Earth. Dr. Gerald P. Kuiper, of Yerkes Observatory at Williams Bay, Wisconsin, estimates that no more than 10 percent of the information available from ground-based study has so far been obtained.

The basic statistics of the Moon have been known for a long time, and probably are accurate to within a very small percentage. We have been saying that the Moon is roughly a quarter of a million miles from Earth. That distance varies as the Moon orbits about the Earth: The Moon can be as close as 221,463 miles, as far away as 252,710 miles. Its diameter is 2,160 miles. It rotates once upon its axis every 29.53 days. As this is also the length of time required for it to make one complete orbit about the Earth, it keeps one face to us all the time. Actually we see slightly more than half of the Moon's surface—59 percent. This is due to the tilt of its axis and a slight wobble in its movement. There is, how-

A typical moonscape, taken by a 12½-inch telescope. The large crater in the center is Copernicus. (Photo by Dr. Strathmore R. B. Cooke)

ever, one side of the Moon, the remaining 41 percent, that we never see.

But now we have a photograph of this hidden side, taken by the Russian moon probe, Lunik III, which circled the Moon in October, 1959, and took a picture of the side never seen by man.

The Moon is a desolate place, more barren than a desert. It has no atmosphere as such, and thus no weather as we think of weather. Because there is no air, there is no sound, since sound is transmitted by air. There is no twinkle in the stars, for it is the motion of Earth's atmosphere that puts the twinkle in them. The sky is not blue, but black. There is no twilight. There are no rosy dawns, no flaming sunsets. All of these, once more, are the products of weather and of atmosphere. And everything, on the surface at least, is completely dry—absolutely waterless.

What will we see when we get to the Moon? What is the surface like?

Desolation, of course; but that desolation must take some sort of shape.

The three most prominent physical features on the Moon are the mountains, the craters and the "maria." The maria are the great flat plains, which the ancients thought were seas. Maria means sea. Most of the maria, actually, are named for water—the Sea of Tranquility, the Bay of Rainbows, the Marsh of Dreams. But don't let anyone fool you—there are no seas or bays, nor even any marshes.

Just how these major formations came about is still a matter of some argument. The best evidence seems to be that the maria are gigantic lava flows—such tremendous flows that they drowned out great areas of the surface and, cooling, left plains as flat and smooth as table tops.

But don't think that this proves that at one time volcanoes spouted on the Moon. If you do, you'll be falling straight

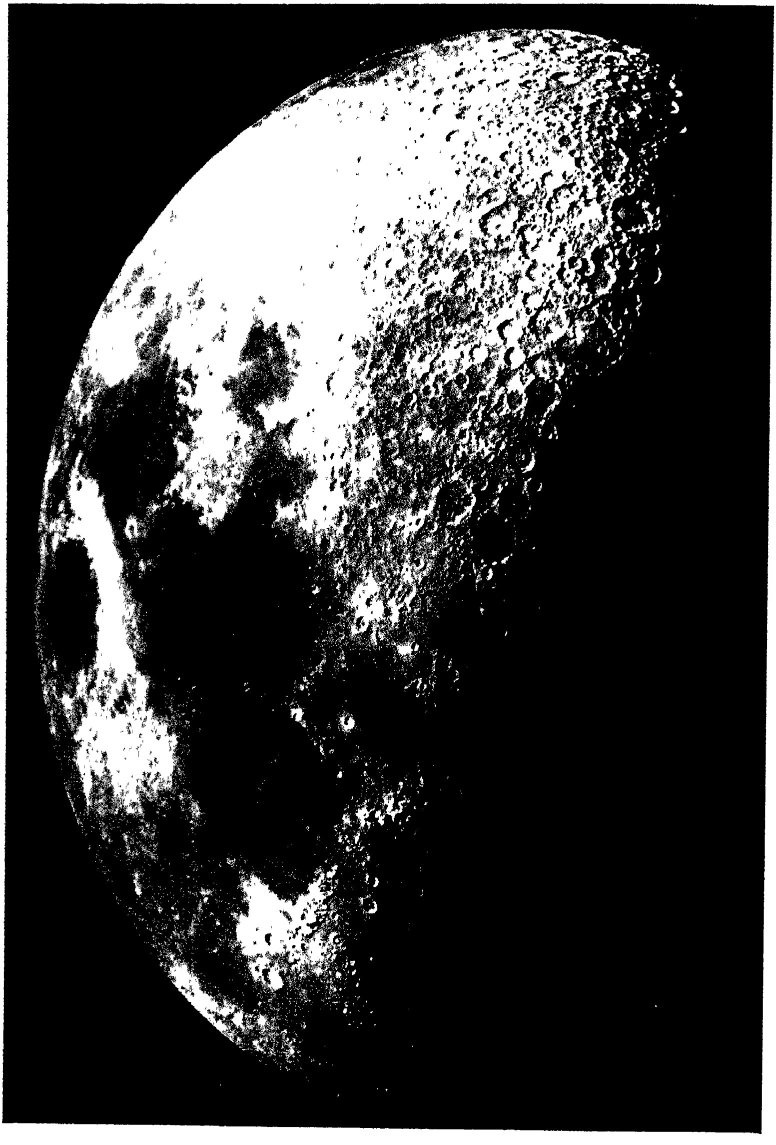
into the ancient argument as to whether volcanic action or meteorites formed the craters. Right now it appears that the case for their having been formed by meteorites is winning out. But there is still a lot of argument for their origin by volcanic action.

In addition to the maria, which appear dark, there are brighter surfaces which are sometimes called the uplands or highlands. Sometimes they also have been called the continents, although they are not continents in the sense that they are lighter rock masses floating in the Moon's mantle, as our continents float in Earth's mantle. Nor are they continents in the sense that they are large land masses rising from the seas, since there are no seas. The best guess is that they are the Moon's primitive crust, not flooded by lava or blasted into craters or wrinkled into mountains.

Some of these brighter areas appear to be strewn with debris thrown out by meteorites striking the surface. But there are a few areas where the surface is undisturbed, where it is, apparently, exactly as it was when the Moon first formed. If this is true, then this fact has importance insofar as man's journeying to the Moon is concerned. If these bright, uncluttered areas actually are the Moon's primitive surface, then they might prove to be the "softest" spots on the Moon for the landing of a spaceship.

A lava flow would be hard; but the Moon's original crust probably would be comparatively soft. Not so soft you couldn't walk across it, but soft enough so there'd be some give to it if a spaceship should come down a bit too hard. It might be compared to crusted snow—standing up under ordinary stresses and pressures, but crumbling when greater pressure is applied. This is a comparison in degree only: The Moon's original crust would be harder, certainly, than crusted snow, but it might react to pressure in the same way.

The craters are the most prominent and unusual feature



The pitted, pockmarked face of the Moon. And only the larger craters are shown. There are many thousands of others too small to show up in this photograph. (Lowell Observatory photograph)

of the Moon's surface. They are almost everywhere. The largest of them are close to 150 miles in diameter; others are less than a mile across. It is likely that there are a number of smaller ones which do not show up in telescopic observation. Something over 30,000 craters have been charted on that portion of the Moon which we can see.

Our largest telescopes bring the Moon close to us. But even so, our telescopic observation is never better than an apparent hundred miles distant—that is, it is as if we were looking at the Moon with the naked eye from only a hundred miles away. Under such conditions, it is hardly likely we'd see anything much less than a mile across.

There are a number of different kinds of craters. The largest of them, from 60 to 150 miles across, are called "mountain-walled" plains. They are only roughly circular, and are surrounded by mountain walls which in many cases are low, just slightly elevated above the plain.

The "mountain-ringed" (not walled) plains measure from 10 to 60 miles across. They are circular, and are ringed by higher mountains with steep inner slopes. This type of crater is far more numerous than are the larger mountain-walled plains. Most of them have large peaks rising in their centers.

"Crater-rings" are yet another type of crater. They are 3 to 10 miles across, are circular and have low walls; but they are sunk deeper into the surface than are the larger formations. Small crater-rings are called "craterlets." "Crater-pits" are shallow depressions, usually without rims. There are thousands of each of these types of smaller craters.

There are names for many other kinds of craters, but the designations refer more to the grouping of the craters than to the craters themselves. Crater chains and chains of walled plains are, as the names imply, groups of craters running in a straight line. Ruined ring-plains appear exactly like

eroded formations, with the rims broken. But the damage probably can be attributed to meteorites ripping holes in the ring-walls, rather than to erosion.

And now that we know something of the craters, how did they come about?

Someone could write a book on the various theories which have been advanced, from time to time, about the origin of the craters.

One of the theories, which now has been dropped, is that the craters were formed by gigantic bubbles of gas rising from the interior of the Moon and bursting when they reached the surface. This supposedly happened in the early days, when the Moon, if not actually molten, was still hot and in a plastic condition. The craters, the theory said, were the scars left by the bursting bubbles as the Moon cooled and solidified.

Another theory was that the Moon was composed of ice, and that heat from inside the Moon resulted in the ice melting in certain areas where the heat was most intense. The rim-walls of the craters are explained, in this ingenious theory, by the idea that water resulting from the melting evaporated, but the water vapor, before it could escape, condensed and was deposited as ice and snow around the cup-like melt area.

There seems to be no question now that this theory is wrong. Rim walls composed of ice and compacted snow certainly would melt in the intense heat of the Moon's two-week day.

But the theory, just possibly, might not be so far afield in another respect: not that the melting of ice accounted for the craters, but that there may be ice on the Moon.

It is generally believed there is no water on the Moon and thus no ice.

But in April, 1961, Dr. Thomas Gold, of Cornell University, suggested that a thick layer of ice may, in fact, lie a hundred feet or so beneath the surface of the Moon.

Gold bases his idea on the fact that silicate rocks contain water, tied into their molecular structure. If the central area of the Moon is hot, as some scientists believe, says Gold, this water would be cooked out of the rocks. Once it was boiled out of the rocks, it would rise toward the lunar surface, where it would either remain as free water or evaporate. Under lunar conditions, it would evaporate.

But, Gold theorizes, the water never reaches the surface. When it comes in contact with the cold upper layers of the Moon, it freezes and forms a thick layer of ice a hundred feet or so below the surface.

If this is so, it means that when man gets to the Moon, he will only need to drill to reach a plentiful water supply. However, there is no way of telling if Gold's theory is accurate. To determine this, among many other things, we must wait until we reach the Moon and see what actually is there.

You may wonder why the surface of the Moon should be cold if it is broiled for two weeks at a time at temperatures above the boiling point of water. The answer may be dust. We'll take a look at the dust idea a little later on.

For the moment, let's go back to the craters.

The theories described—that of the bursting bubbles and that of the melting ice—are only two of the many which at one time were seriously considered as explanations of the origins of craters. Most of them had some logic in their favor, but were discredited, in time, as more knowledge was obtained about the Moon.

The volcanic theory is now beginning to lose some ground, although at one time it was the most generally accepted explanation for the existence of the craters. This does not mean that the presence of volcanoes is entirely ruled out on the Moon; but it does appear that the best evidence, at the moment, is that the craters were formed by meteorites. Some of them may have been formed when the Moon was in

a molten or a plastic condition; but there is no reason that they could not have been formed, just as easily, after the Moon had cooled.

There are many arguments against the craters being volcanic in origin. For one thing, they're too big. For another, their shape is wrong. On Earth, a volcano consists of a volcanic neck funneling molten materials out of the Earth. Through the years, these materials build up into a high, steep mountain, with the mouth of the funnel still at the top.

The Moon craters are not like this at all. Their floors are deeper than the outside plain; they are surrounded by mountain walls; and the outside of these mountain walls are not nearly as steep as the slopes of a volcano on Earth.

If there is, or was, volcanic action here, it would have to be of a different kind than that we know on Earth.

But the craters are very much like something else we do know on Earth: They are a great deal like the crater dug by an exploding artillery shell. They are also very much like the craters dug on Earth by falling meteorites.

A crater dug by an artillery shell, or a meteorite when it falls to earth, is circular or nearly circular. This holds true no matter what the angle of the shell or the meteorite may be when it strikes the ground. The blasted earth forms a rim around the crater exactly like that surrounding the craters on the Moon: the inside slope is steep, the outside slope is gentle. The crater floor is below the level of the ground outside. And the larger the crater, the greater the height of the surrounding wall.

Back in the late nineteenth century an astronomer by the name of Schroeter discovered a rule about the luner craters. He said that if you took all the material in the crater walls and shoveled it back into the crater, the material would exactly fill the crater. That is, the ground would be leveled off and there would be no sign that there'd ever been a crater.

The same rule applies to bomb or shell craters.

We know, however, that no one has been firing shells or bombs at the Moon. So there seems just one other thing which could cause a Moon crater: a meteorite.

One must understand that there is a vast amount of energy involved when a meteorite strikes any surface. The weight of the meteorite, plus its speed, adds up to a lot of explosive force. When the meteorite hits, this energy is converted into heat. The heat is so great that much of the meteorite itself and the ground around it is completely vaporized. These vapors, or gases, are the explosive agents which gouge out the crater.

Scientists have figured out, as a sort of rule of thumb, that a meteorite will dig a hole 60,000 times its own size. This rule will vary, of course, but will be true generally. So, for a crater 80 miles in diameter, we could figure that the meteorite which dug the hole would have been 2,700 feet, or slightly better than half a mile, in diameter. Clavius, the biggest crater on the Moon, measures 146 miles across. The meteorite that blasted it out must have been somewhere between a mile and two miles in diameter.

The fantastically furious explosion which would result from the impact of a large meteorite on the lunar surface also could explain the lava flows which are thought to have created the maria.

Such an explosion would bite deep into the Moon's crust and could unleash a lava flow from far beneath the surface. The lava would pour out and flood adjacent areas until such time as the congealing lava sealed itself in again.

One of the puzzles of the craters is the existence of the central peaks. Not all craters have them, but many of them do.

At one time they were regarded as volcanoes which had spewed out the material that formed the crater's outer walls. Now they are believed to be due, possibly, to the rebound action of the Moon's surface after the meteorite's impact. While the rebound suggestion makes sense if the Moon was

plastic when hit by the meteorite, it is hard to understand how it could have happened on a solid surface.

So far as volcanoes on the Moon are concerned, we may now have evidence not only that volcanoes once existed on the Moon, but that they may still exist.

And this evidence, like almost every new idea about the Moon, has created a storm of controversy.

On November 3, 1958, N. A. Kozyrev, a Russian astronomer, was taking a spectrogram of the Moon at the Crimean Astrophysical Observatory.

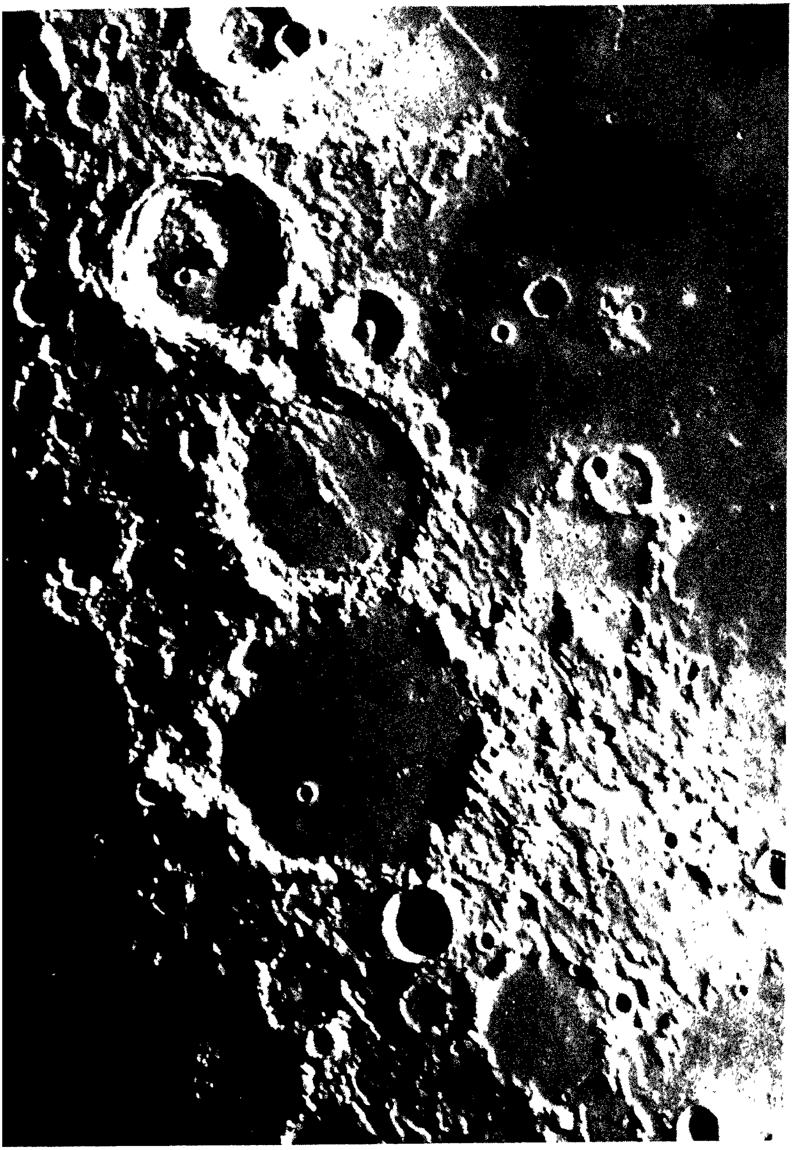
A spectrogram, very roughly, is a picture of the light emitted or absorbed by whatever object the spectrographic apparatus may be trained upon. It is based upon the separation of light into its component parts when it passes through a prism. You yourself can break down light by holding up a triangular piece of glass (a prism) against the sunlight. In the glass and in the reflection beyond it you will see a rainbow of color. This is the sunlight, broken up into its several parts. The spectrographs used by astronomers and other scientists are pieces of apparatus greatly improved over the simple prism, of course; but the principle is the same.

From a spectrogram, an astronomer is able to analyze the light which he has photographed. By this analysis he is able to determine the source of the light—that is, what sort of atoms emitted it.

So on this November night, Kozyrev was taking a spectrogram of the crater Alphonsus on the Moon, with the slit of the spectrograph centered on the central peak.

While he was doing this he looked through the guiding eyepiece of the telescope and noticed that the peak was suddenly washed out, and that it had an unusual reddish tinge. He put this down, however, to poor seeing due to atmospheric motion.

Having finished the spectrographic work on Alphonsus,



This photograph of the lunar surface, taken with the 60-inch reflector of the Mount Wilson and Palomar observatories, shows the crater Alphonsus. It is the middle crater of the three large ones shown in the picture. (Photo courtesy of Dr. Dinsmore Alter)

he turned the telescope on Mars. Two hours later he retrained the telescope on Alphonsus. At that time he noticed that the central peak was unusually white and bright. During the next thirty minutes the peak faded to its normal appearance.

He thought nothing of this at the time, once again believing that a shifting atmosphere was playing tricks on him.

But when he developed his spectrographic plates, he found that something had been happening in Alphonsus. In the second spectrogram he found indications of the presence of carbon-2, a spectrum which one would not expect to pick up on the Moon, but which one would expect in volcanic gases.

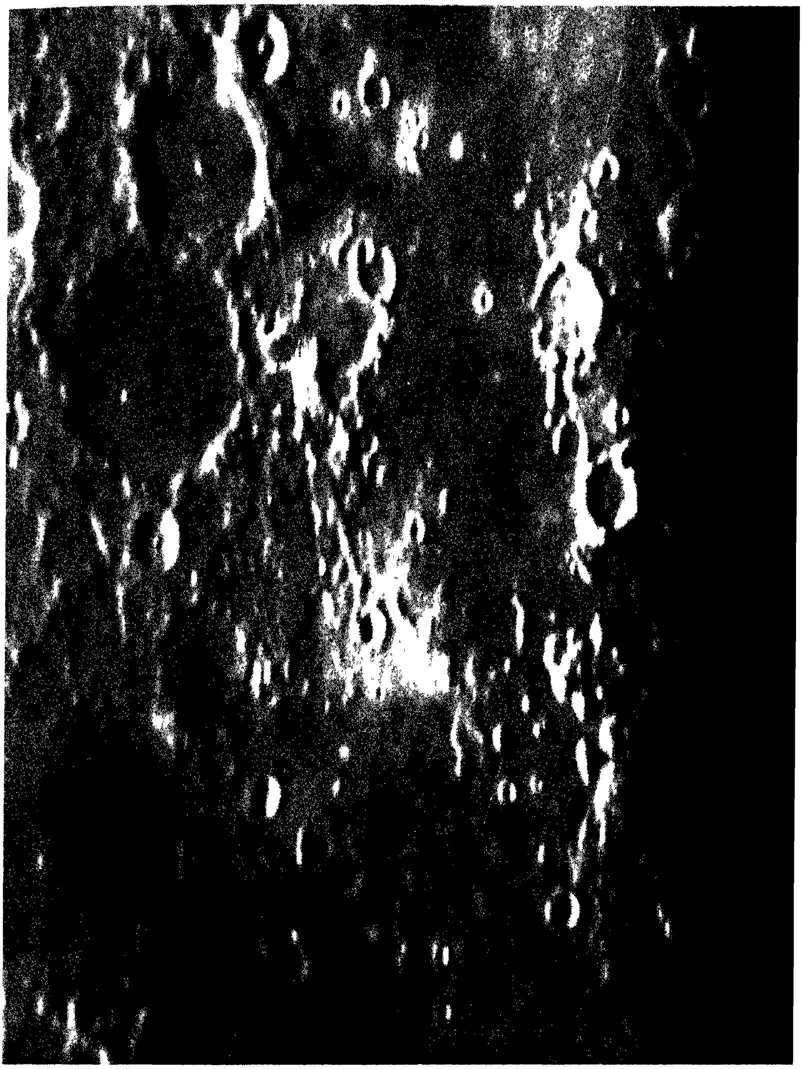
Which seemed to mean that he had seen a volcano in eruption on the Moon—a very brief eruption, no more than a puff of gases—but a volcano in action.

His announcement of this finding stirred up considerable discussion. Some of those astronomers who are convinced that there are no volcanoes on the Moon, and never have been any, were openly skeptical. Many others displayed varying degrees of caution in accepting the finding. At the moment, probably two out of every three astronomers would be inclined to doubt Kozyrev's interpretation of what he saw in Alphonsus.

About six months after Kozyrev made his report public, two amateur astronomers in the United States made an announcement which seemed to bear out the contention of the Russian scientist.

In a paper which appeared in the Publications of the Astronomical Society of the Pacific, H. F. Poppendiek and W. H. Bond revealed that they also had seen some funny goings-on in Alphonsus.

On November 18, 1958, they wrote, they had seen a cloud completely blot out the central peak. The cloud, they



This photograph of the crater Alphonsus, the topmost large crater in the upper left hand corner, shows several of the dark spots for which the crater is noted. The photo was taken with a 12½-inch telescope. (Photo by Dr. Strathmore R. B. Cooke)

calculated, was about 20 miles in diameter, somewhat ragged in shape and with a strange brightness about it. They had watched the cloud for half an hour or so.

But it just so happened that on that same night, and at the same time that Poppendiek and Bond were looking at Alphonsus and seeing the cloud, another amateur astronomer, Walter H. Haas, also was looking at the crater. In a published paper, Haas wrote that he had seen no evidence of the cloud.

All three of these amateur astronomers are competent observers. How come two of them saw a cloud, while the other one did not? What is going on in Alphonsus, anyhow?

Again, we can't imagine. We'll simply have to wait. All the evidence is not in.

Alphonsus was an object of interest long before the cloud (if there was a cloud) was ever sighted, because the crater's floor is marked by five black spots. Alphonsus is not the only place where spots of this kind show up; but it is a classical example of such places.

What the spots may be, no one knows. At one time it was speculated that they might represent vegetation; but we know now that that is unlikely. Another guess is that they may be small areas of lava, long since congealed. They seem to be in the form of depressions. But there is no proven explanation of what they are.

Because of its deadness, one is tempted to say there is never any change upon the Moon—that it is the same today as it was a billion years ago. And that, barring change by man, it still will be the same a billion years from now.

But this is not necessarily so. For aside from the reports of the possible volcanic action in Alphonsus, there have been other changes reported. None of the reports have been proved, of course. But reports of change do come with enough regularity so that one can't escape the thought that things may be happening.

Clouds have been reported, on several occasions, in the crater Linne. Flashes of light have been reported from time to time; these could have resulted from the explosion of sizeable meteorites upon impact on the Moon. A few years ago what appeared to be a newly-formed natural bridge was reported on the border of Mare Crisium. Closer examination of the area seems to indicate that the bridge was no more than a deceptive arrangement of shadows. But was it? Again, no one can be sure.

The trouble, of course, is that we have nothing approaching a detailed map of the Moon. We have several excellent maps of the Moon, both drawn and photographic; but these are large-scale.

An amateur astronomer, Dr. Strathmore R. B. Cooke, who is also head of the School of Mines and Metallurgy at the University of Minnesota, is now engaged in a project which, if it were concerned with the entire surface of the Moon, would give us the kind of map against which we might check to determine whether there had been any change in our satellite's surface features.

Cooke is engaged in mapping areas of two to three thousand square miles in extent, on a scale of approximately ten miles to the inch. This involves tedious and painstaking work, measuring shadows and determining the angles involved. He is doing the work for his own gratification, as a hobby, and has no plans to cover any significant portion of the Moon's surface. But it is well to point out that, due to the lack of a map of this sort, changes on the Moon may have been missed time and time again because there was no detailed reference against which to check.

Amateur astronomers have contributed a good deal to the study of astronomy. There are some thousands of them the world over, and they range from men who simply like

to look at the planets and the stars through their own telescopes to others who perform significant chores and publish professional papers. Many of these men are not amateurs in the strict sense of the word, but part-time professionals.

Aside from the reported (but seldom confirmed) major happenings on the Moon, there are little things going on all the time. The surface is pelted continually by a rain of tiny meteorites—and occasionally, more than likely, by a big one. It is swept by cosmic rays from deep space, and by the solar cosmic rays and other particles thrown out by the Sun. Eternally the hammers of extreme temperature changes keep chipping at its rocks. Taken all together, this is weather on the Moon.

And, says Dr. S. Fred Singer, of the University of Maryland, the Moon may well have dust storms. Not great blinding ones such as swept the western prairies of the United States during the thirties, but just little dust storms.

He believes that during the Moon's daylight hours, radiations from the Sun knock negative electrons loose from the surface of the Moon. This leaves the surface with a positive electrical charge. When meteorites hit the surface, they stir up small clouds of dust. The dust particles also are positively charged and bounce about, like a cloud of fleas on a hot pan, repelled by the positive charge of the surface. Once started bouncing, they don't settle down until the lunar sunset. At that time the Sun's radiation is blocked out. In consequence, the particles lose their charges and the "dust storm" ends.

Which brings us to the matter of Moon dust.

We know that it is there; but here again is another controversy. Some experts on the subject of the Moon believe that the dust is only a few inches thick. Others are inclined to think it may be many feet deep. Gold, in 1955, published

a paper in which he theorized that the maria were not lava flows at all, but great basins filled with dust hundreds of feet deep.

But, first, how do we know about the dust?

The story involves an instrument called a thermocouple. It is used by astronomers to determine the heat of the planets and the stars. Determinations are made by measuring the infra-red rays originating from the body under study. Infra-red rays are heat rays.

A study of the Moon's surface has shown that during an eclipse, or when a portion of the Moon moves into shadow, the surface cools swiftly. This means that no great amount of heat is stored in the surface, that most of it must be reflected away from the surface. And this, in turn, suggests the presence of some sort of insulating material. Dust is the rather obvious answer.

Moon dust, however, would not be like the dust we know on Earth. Earth dust is soft and fluffy. Moon dust would be packed tight together, since there are no gases (since there is no atmosphere) to hold the particles of dust apart. Without air, the dust particles would move close together, with very little space between them. You probably could walk over a layer of Moon dust and not make any tracks.

The Moon dust might have been formed by any or all of three processes. The continued fall of meteorites for billions of years has been chewing up the surface, and some dust would result from this. The extremes in temperature flake away surfaces, creating more dust. Solar radiation and ultra-violet rays are absorbed by a thin layer of the material on the surface of the Moon, and this would have the effect of breaking up some of the surface layer. All three processes are slow. Not much dust would be added in any one year,

nor in any hundred years. But in several billion years, clicking meteorites, chiseling radiation and changing temperatures would chew up a lot of the surface material.

Dr. Fred L. Whipple, head of the Smithsonian Astronomical Laboratory, believes that a great cloud of extremely fine dust from the Moon may be circling the Earth. We do know that there are great layers of dust above Earth's surface.

Whipple believes that the dust is puffed out into space when meteorites strike the surface of the Moon. The dust would be thrown into space above the Moon by the impact; and, because of the Moon's slight gravity, some of it might escape from the Moon's attraction.

Such dust theoretically would spiral slowly toward the Earth, to form, finally, into a fairly evenly-distributed cloud about the Earth.

Whipple theorizes that the Moon may actually be losing some of its mass as a result of the continuing loss of dust into interplanetary space. It gains some, too, of course, in the meteoric material which falls and puffs out the dust; but Whipple is inclined to think that the loss in dust may outweigh the mass which is gained from the bombarding meteorites.

Each year the Earth gains many tons of mass by the dust, originating from the Moon or elsewhere, which continually sifts down through the atmosphere.

Time and again we have said that the Moon is airless, although technically it may have an extremely thin atmosphere. And you may wonder why this is so.

It all ties in, as does the matter of escaping dust, with the fact of the Moon's lesser gravity—only one-sixth that of Earth's. This low gravity means that escape velocity from the Moon is much less than escape velocity from Earth. On Earth, the escape velocity is 7 miles a second—that is, any object, to escape from the attraction of the Earth, must travel

faster than 7 miles a second. On the Moon, the escape velocity is only 1.5 miles per second.

Escape velocity applies to molecules as well as to spaceships. It just happens that the velocity of a hydrogen molecule, at ordinary room temperature, is 1.5 miles a second. At higher temperatures, its velocity increases. Thus, with the Moon heating up during its long day, hydrogen wouldn't remain on the Moon, but would go popping into space. Oxygen and nitrogen, being heavier than hydrogen, might stick around a little longer; but eventually, they, too, would wander into space.

So, if the Moon at any time did have an atmosphere (and we cannot rule out the possibility that at one time it did) that atmosphere, early in its history, seeped out into space.

Because of the Moon's lower gravity, and consequently its lower escape velocity, it is entirely possible that sizeable chunks of Moon material, in addition to the dust, may at times have been hurled off the Moon by the force of meteoric impact.

Once these chunks of the Moon were thrown into space, they would have fallen into orbit around the Earth. There is some belief that some of the meteorites which have fallen on the Earth or burned up in Earth's atmosphere may have been these chunks of Moon material. While there is no agreement on it in scientific circles, it is possible that pieces of the Moon may lie upon the Earth today.

We have talked about the maria, the so-called uplands, and the craters. How about the other features of the Moon?

There are mountains, too, almost as high and rugged as any to be found on Earth. At one time it was estimated there were peaks on the Moon as tall as Mt. Everest, which, at 29,000 feet, is the highest mountain on the Earth. But it is now believed that these heights have been overestimated. Perhaps the Moon has no peak higher than 25,000 feet. But,

considering the size of the Moon, its mountains, comparatively speaking, are much higher than are Earth's.

One of the most baffling features of the Moon is the "rays." The rays are bright streaks which extend out from many crater formations. In many cases they run for hundreds of miles over the surface before they dwindle off. There has been speculation that they may be lines of flour-like dust. But the question then is posed: How did the dust get there? And, as so often is the case, there is no ready answer.

Other streaks on the Moon, called "rills," are believed to be great chasms gashed into the lunar surface.

Early in October, 1959, the Russian space probe, Lunik III, orbited around the Moon, took pictures of the hidden side, and transmitted these pictures back to Earth.

As might be expected, the pictures are crude. But they do tell us something about the hidden side. The technical problems involved in doing the job are touchy, and any results at all are a tribute to man's scientific ability.

Contrary to general expectations that the hidden side of the Moon would differ very little from the side we see, there do seem to be marked differences. For one thing, there are far fewer maria, and those there are appear to be smaller than the ones we see. The landscape is dominated by mountains. There are craters, but no large ones; the largest measures only 43 miles across.

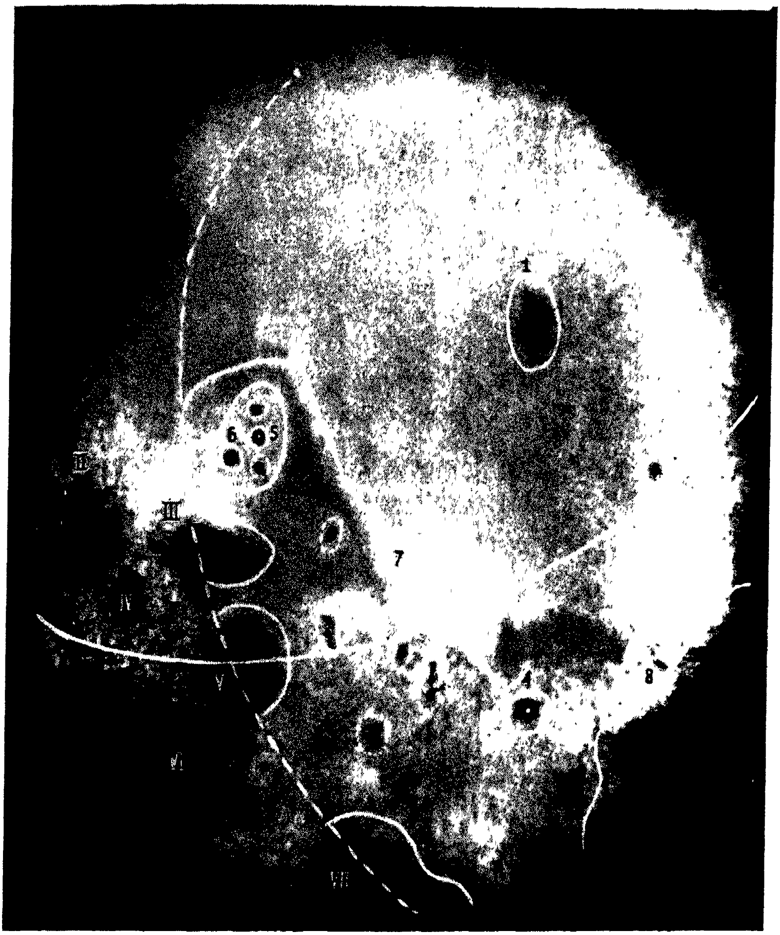
And here, again, is another puzzle for science: Why should the two sides of the Moon be so markedly different?

The Moon, as you realize by now, is full of questions and of puzzles.

And the biggest of them all we've left to the last: Is there now, or was there ever, life upon the Moon?

The answer is, probably not.

Conditions on the Moon—the seeming lack of water, the utter lack of air, the great temperature changes—would well-nigh make life impossible, at the moment.



A Russian photograph of the hidden side of the Moon, taken by a camera in a space probe which circled the Moon. The unbroken line marks the lunar equator, while the dotted line separates the face of the Moon which we can see from the hidden side. Roman numerals mark those familiar features of the Moon which can be seen from Earth, while the Arabic numerals mark features never seen by man. Most prominent of these features is (No. 1) a large crater named the Sea of Moscow and measuring almost 200 miles across. (Sovfoto)

Yet some scientists suspect that "pre-life" molecules may be found there.

One theory of the rise of life on Earth is that large and complex molecules formed from the primeval gases in space, and that some of them finally drifted in and settled on the surface of the Earth. According to the theory, these molecules then reacted with other substances in the weird chemical brew which made up the early stages of Earth's atmosphere, and from this reaction the first simple forms of life emerged.

It might be well to point out here the distinction between "pre-life" molecules and the "life spores" which were mentioned in the chapter on the origin of life. The "pre-life" molecules would in no sense have been alive themselves; they were simply one of the building blocks from which life could have arisen.

If the theory that life arose from pre-life molecules is true, then some of the molecules may likewise have landed on the Moon and must still remain there. Earth, at the time life first formed, was a seething laboratory, crowded with compounds which would have encouraged reaction in the molecules. Apparently nothing of this sort existed on the Moon—there was no seething laboratory. The molecules, if in fact there were any, and if in fact they landed on the Moon, must have found a dead end there. There was nothing on the Moon to prod them into life. They'd have had to stay just big, complex molecules. (By big, of course, we mean big for molecules. There'd have to be several billion of them, all crowded together, before we'd ever see them.)

If they landed on the Moon, the chances are they're still there. There'd be no place for them to go; not a thing to do. They'd have to stay on the Moon, unchanged.

If we should find them when we reach the Moon, we'd be one great step nearer to an understanding of the origin of life.

Here is a clear example of the reason for the warning biophysicists have issued against the contamination of a planet before it can be studied. On a body such as the Moon, where the atmosphere, if there is any at all, is so slight, contamination becomes a real threat.

It has been estimated that a lunar atmosphere could not possibly contain more than one hundred tons of material—and probably as little as ten. By comparison, Earth's atmosphere is composed of six trillion (six followed by twelve zeroes) tons of matter.

In such a thin atmosphere even the fumes from the landing rockets of a spaceship could so contaminate the atmosphere that it would never be the same again. The introduction of bacteria of any sort could so change the record that later studies never could make sure whether a bacteria belonged to the Moon or was an alien intruder. (Any bacterium from the Earth would be an alien if it intruded on the Moon.)

So far as the Moon is concerned, the harm may already have been done. On September 13, 1959, a Russian moon probe smacked into the Moon. It may lie there today in a pit dug into soft material. Or it may be gone forever, having flared out in a flash of energy, destroying itself, if it hit a solid surface.

Niklos Lovas, of the Csilleberc Observatory of the Hungarian Academy of Science, announced that while watching through his telescope he saw the moon probe land. Well—not the rocket, actually, but the cloud of dust it raised. He placed its point of impact in that area of the Moon known as Palus Putredinis (which means the putrid swamp). Astronomers, taking note of Lovas' report, term it one of the luckiest observations on record. The Russians could not possibly have predicted where the rocket was to land. They were doing very well, indeed, to hit the Moon at all. And the Moon is a good-sized object to view through a telescope. To

get any detail, you take in only a small segment of it in the glass. The cloud of dust the rocket raised must have been of good size; but since there is no air to hold it suspended, it would have settled quickly and been visible for only a few minutes.

The Russians may have sterilized their moon-probe before they shot it into space. Even so, the chances are excellent that some earthly bacteria, carried by the probe, are already on the Moon.

7.

And When We Get There?

WITHIN THE NEXT TEN YEARS, PROBABLY BEFORE 1970, we will have some first-hand knowledge of the Moon. Man, by that time, may have reached the Moon himself. If he has not, he will have sent one of his machines to collect knowledge for him.

Only a few years ago a proposal to land a laboratory on the Moon and operate it by remote control would have been regarded as arrant foolery. But today it is being planned in all seriousness. In the next few years we'll do it.

Putting such a laboratory, or instrument, or whatever you may want to call it, on the Moon, and expecting it to work after it has landed, will call for a "soft" landing. By a soft landing, we mean a gentle landing. The rocket vehicle which carries such an instrument to the Moon must be equipped to fire retarding rockets to cut the ship's speed so that the landing will be easy.

Man already has made a "hard" landing on the Moon—the Russian probe that smacked into its surface.

But a hard landing is of little use. During those last few minutes before it smashed to destruction, a hard-landing instrument might get back to us some word of data it had gathered. But seconds later it would have hit the surface and would be of no further use.

The Russians announced that data obtained from their impact shot seemed to indicate that the Moon had no magnetic field. But whether the data the speeding probe was able to send back in its last few seconds was sufficient to establish this beyond any doubt is debatable.

Before we actually land an instrument on the Moon, we'll probably place an instrument-equipped satellite in orbit about the Moon. Such a satellite could send back considerable lunar data. It would be especially helpful in mapping the Moon.

But nothing, short of man himself, will do the job as well as a robot laboratory actually put down in working order on the lunar surface.

We haven't such a robot laboratory yet, although there is no doubt that we are capable of building one. A few engineering problems still remain, but none that should give us too much trouble.

John Bensko, a scientist at the research projects division of the George C. Marshall space flight center at Huntsville, Alabama, in the fall of 1960 outlined before a meeting of the American Geophysical Union some of the specifications and problems with which we would be faced in putting a robot on the Moon.

The robot, he said, would be equipped with a television "seeing eye" which would practically enable a man on Earth to ride along with it. Through the use of the "seeing eye," an Earth-based operator could watch the rocket-robot speed

through space, and could, by remote control, bring it safely to the surface of the Moon. Once it was down, the operator could continue to command its operations, again by remote control, and could monitor its work.

If a robot vehicle landed on the Moon at the beginning of the lunar day, its instruments, powered by the Sun, would have two weeks of uninterrupted operating time.

Once the two-week lunar night had fallen, storage batteries would be used for operation and for heating, which would be necessary to protect the instruments from the cold.

The robot, as Bensko sees it, would be guided directly by the television link with Earth. An operator could see what was happening and what needed to be done, and could operate the machine by remote control.

Television pictures of the lunar surface would be sent to Earth by the cameras in the robot. All other information and data would be sent back to Earth in a continuous stream by radio. The data observation would, in all probability, be as good as a man on the Moon could furnish; for the robot would be using the same detecting instruments as a man would use.

As well as controlling the robot's movement and keeping tab on its work, an operator could alter, as necessary, the predetermined, set program of work which would have been fed into the robot before launching.

In addition to the television apparatus, the robot probably would carry a gravimeter to take gravity measurements, seismic apparatus to probe (by sound signals) the interior of the Moon, thermal devices to measure the heat of the Moon's crust and the changes in the surface temperature, gas detection gauges to measure the atmosphere (if any), a gamma-ray spectrometer to measure radiation, and other instruments to study electrical and magnetic fields (again, if any). There may be many other instruments, of course, but

these are the ones which would surely be included. It is likely that some method would be worked out to provide us with a chemical analysis of the lunar surface material.

The robot probably would move about on wheels or tractor treads. Bensko is convinced that the Moon's surface would be negotiable for a wheeled vehicle.

The dust, even if it were deep, he says, would be firm enough for the robot to move about on in perfect safety. He believes that the dust, because of the lack of air to hold its particles apart, has become firmly bonded together to form a brick-like material.

If there were treacherous spots, these could be detected by sounding equipment, and the machine could be guided around them.

Once we get sufficient booster power in our rockets to handle the load, we can put such a robot on the Moon. The remote-control principle is entirely possible. But there are a few remaining engineering problems still to be solved. All of these relate to conditions on the Moon.

Four factors, Bensko says, must be taken into consideration by those who design a Moon instrument. These four conditions are: the high vacuum which exists on the Moon; the great temperature range; the intensity of the solar radiation; and the possible hazard of the impact of tiny meteorites.

Under the first three conditions, most organic material would break down. This applies particularly to oil, which is derived from plant (and to a small extent, animal) life which existed on the Earth millions of years ago. Organic lubricants would stand up for only a short time; then, under high temperature, in a vacuum, they would evaporate.

At extremely low temperatures most plastics become brittle.

Silicone rubber and teflon plastics, reinforced by fiberglass to absorb the radiation, would stand up under lunar

conditions. Instead of copper, aluminum would be used for electrical conductors. Solid inorganic lubricants would have to be developed. For structural design, aluminum would be used; not only could it exist under lunar conditions, but its weight is light. Certain stainless steels and titanium alloys also would be satisfactory. Exposed surfaces would be painted with inorganic paints.

Many ceramics (materials made of earths, like pottery and china) could be used in the structure of the machine. Preference would be given to those which have very little heat expansion and are resistant to radiation. Radiation-resistant glass would have to be used for windows, lenses and filters.

Under the high-vacuum conditions, ceramic powders and foamed ceramics would be best for the insulation which would be necessary to protect the machine and instruments from excessive heat and cold. Heat protection could be provided also, more than likely, by the use of solar radiation shields—highly reflective material which would bounce the Sun's rays away from the robot.

One real headache would be the designing of the electronic circuits. These would be the most important part of the entire machine; for if the electronic circuits should fail, the robot and its instruments would go dead. Transistors probably would be used extensively, and both these and photomultiplier tubes (for the television apparatus) can operate only within a very narrow range of temperature. Either we will have to find a means to protect them from the Moon's great temperature ranges, or we will have to design new mechanisms which can operate at greater temperature extremes.

But all these problems, formidable as they may sound, can be solved on the basis of our present knowledge and technology. We have, in the past, cracked much tougher ones.

When man himself gets to the Moon, he will face conditions which men never before have been called upon to face. When he steps down from his spaceship, he will, in fact, be stepping out into naked space. He'll have solid ground to stand on, and a feeble gravity to hold him there; but otherwise the conditions will be essentially space conditions.

There'll be no air, but there will be radiations from the Sun, and far-traveling cosmic rays which may have come from unknown light-years out in unguessed space.

The Moon probably has no magnetic field; and without a magnetic field, there'd be no Van Allen belt to trap incoming radiation. The Russians announced that their hard-landing shot to the Moon radioed back the information that there is no magnetic field. But this had been guessed by scientists long before the Russian shot was made. It is believed that, to have a magnetic field, a planet must have an iron core. To the best of our knowledge, the Moon has no iron core.

On a satellite without either an atmosphere or a radiation belt, man would be as exposed to all the radiations, as if he were out in space. There'd be nothing to protect him from the deadly proton storms spawned by the solar flares.

Probably one of the first things a man who reached the Moon would have to do would be to dig an underground shelter. That, or locate a cave or a deep crack in the crust to which he might run for shelter. If he were in radio contact with the Earth—and he certainly would be—he could be given ample warning of a proton storm, and could get under cover with time to spare.

The Moon is a hostile place. It was never meant for man. But meant for man or not, man is going there. In going, he'll face terrible dangers—even more terrible because many of them will be unsuspected and unknown. We can detect some of them; we can guess at others. But we'll never know all of them until we finally get there.

On the Moon, as indeed on all the other bodies in the solar system, a man would have to wear an insulated spacesuit, carrying its own air supply and equipped, according to the time of lunar day, with either a heating or a cooling device.

A spacesuit, at best, is a danger in itself and an awkward thing to wear. Should it fail in any way, a man's life would be in danger. Aside from the chances of its failing of itself, there is always the danger that a snag on a sharp outcropping or a hit by a tiny meteorite might put it out of kilter.

Whether a spacesuit must also carry a lead lining to screen out radiation is something we won't know until we learn more about the radiations.

Getting to the Moon, of course, is the first big job. After that there'll be the problem of building a permanent base, and of sending out exploration parties. The base probably would be built underground. Supplies would have to be ferried up from Earth, although there is a good possibility that algae tanks might be used to supply food and to replace oxygen, exactly as they would be used in long-flight spaceships.

Later on, "hydroponic gardens" might be set up to help provide food for a Moon base. Hydroponics is the science of growing food without soil. Plants are grown in tanks of water to which the chemicals necessary for growth have been added. Hydroponics is a tricky business, requiring close attention. But the yield is high and success would cut down substantially on the amount of food which would have to be brought from Earth.

Actually, the algae tanks, in a sense, would be hydroponic tanks. But algae are a natural water-plant. Once the hydroponic gardens were started on the Moon, all sorts of vegetables ordinarily grown in soil would be grown in tanks.

Once man is established on the Moon, he will have gone

more than halfway to the rest of the solar system. Not in distance, of course, for he'd still be only a quarter of a million miles from Earth; but so far as energy and effort are concerned, he'd be a good halfway. With a spaceport set up on the Moon, our ships could set out from there, needing an escape velocity of only 1.5 miles a second rather than the 7 miles per second which they would require to escape from Earth.

8.

Mercury: Closest to the Sun

THIS CHAPTER WILL BE SHORT, FOR THERE IS VERY little that is known about the planet Mercury. There is a good deal of astronomical data concerning it, but of a sort which is principally of interest to an astronomer. It deals largely with the planet's orbit, and is of little value unless you're working with a telescope.

Mercury is the planet closest to the Sun. Its orbit is not a perfect circle; nor, indeed, is any planetary orbit in the solar system. But Mercury's orbit is highly elliptical. At its closest, Mercury is 28.6 million miles distant from the Sun. At its farthest, it is 43.4 million miles distant. Its mean (average) distance from the Sun is 36 million miles.

Mercury passes around the Sun once every eighty-eight days. Like the Moon, the period of its rotation on its axis is the same as its orbital period, so that it always keeps the

same face to the Sun, exactly as the Moon always keeps the same face to the Earth.

Because of its lopsided orbit, Mercury's orbital speed is a jerky sort of business. When it is close to the Sun, the gravitational pull of the Sun speeds it up to 35 miles per second. But as it swings out to its farthest distance from the Sun, it slows down until it is moving at only 23 miles a second. Then, circling in toward the Sun, it begins to pick up speed again.

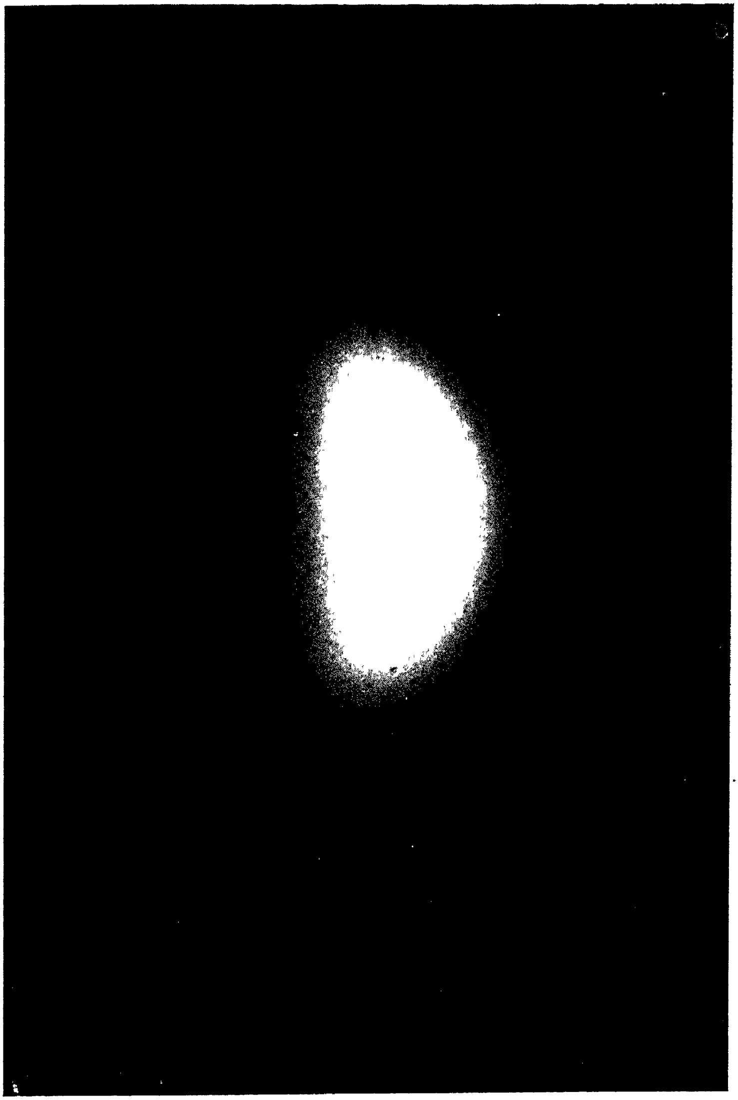
Mercury is only slightly larger than the Moon. Its official diameter is 3,010 miles; but this may be in error by a few miles because of the difficulty in measuring it.

Because it is so near the Sun, Mercury is hard to observe. At certain times it can be seen low in the west at sunset; at other times, low in the east just before dawn. Most people have never seen it at all.

Most of the telescopic work that has been done on Mercury has been carried out in daytime. The morning and evening hours, when it can be seen with the naked eye, are unsatisfactory for observation because the telescope must aim at it along the horizon and thus through a dense blanket of atmosphere.

Of all the planets, Mercury is perhaps the weirdest. It is at once the hottest and the coldest. The side of it which faces the Sun reaches a temperature of around 700° Fahrenheit. The dark side, eternally facing away from the Sun, probably reaches a temperature close to absolute zero, which is 460° below zero. Anything reaching absolute zero is as cold as it can ever get. Absolute zero is the point at which an object has no heat at all.

The coldness of the night side of the planet is explained by the fact that Mercury has only the slightest atmosphere, if any. Since there is no atmosphere, or at best very little, there are no air currents to carry the heat of the sunward side around to the night side.



Mercury taken with the 24-inch refractor telescope. Mercury is a hard object to photograph because of its nearness to the sun. (E. C. Slipher, Lowell Observatory)

At its closest approach to the Sun, the sunward side of Mercury receives ten times as much heat and light as falls upon the Earth. The night side receives absolutely no solar light or heat.

Between the night and sunward sides lies what is known as the twilight zone. To explain this, we'll have to modify just a bit what we said earlier about one side of the planet being eternally in the light and the other side eternally in the shadow. Mercury has a wobble, called libration, just as has our Moon. The wobble is not pronounced; but it does mean that there is an area in this middle world, between the dark and light sides of Mercury, which at times may either be in the dark or the light. About three-eighths of the planet is eternally in the dark, another three-eighths eternally in the light. A quarter of the planet's surface lies in the twilight zone.

The twilight zone is a strange place of alternating brightness and darkness—blazing hot at one time, frigid at another.

The wobble in Mercury is not due to any irregularity in its planetary motion, but to the fact that, as we have seen, its orbital speed about the Sun is not constant but varies from 35 to 23 miles a second. Thus the rotation and the orbital speeds get out of step and produce the wobble.

If the rotation and the orbital speed were in step at all times, the Sun, seen from Mercury, would appear to stand still in the sky. But since they are not and the planet has a wobble, the Sun performs a crazy waltz across Mercury's sky. In the twilight zone it pops up above the horizon, then pops down, then pops up again—a hare-brained succession of sunsets and sunrises treading on one another's heels.

It'll be a long time before man goes to Mercury. Eventually, we may suppose, he'll land on the tiny planet. But there are several other places where he'll go, or try to go, first: the Moon, Venus, Mars, the moons of Jupiter. All of

them are likely to be more hospitable than stovetop-icebox Mercury.

Not only would the place be inhospitable; it would be highly dangerous as well. Not only would there be the deadly heat and the equally deadly cold; but this close to the Sun, it might be guessed that the radiations would be murderous.

We can speculate and imagine, but we probably can't come even remotely close to what conditions would be like on Mercury's sunward surface.

It would be hot, of course. At 700° or more, lead, bismuth and a number of other elements would be in a molten state. If there is lead on the surface, we might expect to find lakes and puddles of it. Sulphur and mercury, if present, would be gases. If there is an atmosphere, it is likely that it would have some sulphur and some mercury in it. With an escape velocity of just slightly more than 2 miles a second, and with the overwhelming heat which would serve to speed up the molecules, none of the lighter gases would be found. They would have escaped into space billions of years ago. In any case, any atmosphere that might be present would be so thin it would qualify as a vacuum.

Some of the gases might drift around to the dark side, and would be permanently embalmed there as solids or liquids by the bitter cold. There we might just possibly find oceans of liquified gases and glaciers of frozen carbon dioxide and oxygen.

There have been those who imagined the sunward side of Mercury as a land of raging volcanoes, pouring out clouds of gases which eventually drifted around to the dark side and were trapped forever.

But there is no basis for this belief. The sunward side, more than likely, is a bone-dry desert, dead these many ages, baked by the terrific heat of the Sun, lashed by solar radiations.

There the Sun would appear twice as large as when seen from Earth, and would be ten times as hot and fierce. The sky would be black because of the lack of an atmosphere.

The one good purpose to which we might put Mercury would be that of furnishing the site for a solar laboratory to study the Sun. From a distance of only 36 million miles, with no atmosphere to distort the seeing, with the Sun itself in the sky at all times, we could learn much more about the Sun than we ever could on Earth, working from the bottom of our oceans of air and at almost three times the distance.

Once can imagine that the task of setting up and maintaining a solar observatory on Mercury would present almost insurmountable difficulties. Setting up an observatory on our own Moon would be bad enough; on Mercury, the job would be a good deal worse.

The telescope shows permanent geographical features on Mercury. It is a geography, however, about whose meaning we can do little more than guess.

The Italian astronomer, Schiaparelli, in the 1880's, was the first man to draw a reliable map of the planet; his map showed dark patches and well-defined darker streaks against a lighter background which appeared to be generally pinkish. Modern day astronomers have carried on this mapping, but with very little improvement over Schiaparelli's.

Just what these dark patches and dark lines may be, we have no idea. One is tempted, of course, to guess at mountains and deep, shadowed canyons. But the evidence is so slight there is no way of knowing.

There is some evidence that, at times, what appears to be white clouds float over the darker markings on the planet. There is no question, of course, that the clouds would be far different from anything we know on Earth. Water vapor, of which our clouds are formed, simply could not exist on Mercury.

If Mercury has an atmosphere, it is an extremely thin one. An atmosphere of some sort is necessary to support clouds. One is tempted, again, to imagine that the clouds might be dust or gases belching from volcanoes.

In a thin atmosphere, this is about the only way that a cloud of dust could form. Even if Mercury were covered with fine dust, it would take a wind to stir up the dust into a cloud. And wind is impossible to come by in a thin atmosphere.

While volcanoes would seem the one possible explanation, their existence, too, is most unlikely. Mercury, on the best evidence, is a dead world. Over the billions of years it has existed, it has been wrung dry of all its reactions. If there were volcanoes at one time, they must long ago have ceased to be active.

At one time it was believed that there was a planet even closer to the Sun than Mercury. In 1860, a great astronomer by the name of Leverrier, the director of the Paris Observatory, began a search for the planet, which he was convinced was there. About the time he started the search for the planet, which he had named Vulcan (naming it even before he found it), a French doctor by the name of Lescarbault wrote him a letter. Lescarbault wrote that he had watched Vulcan crossing the face of the Sun. Leverrier checked the doctor's evidence and confirmed the discovery.

Vulcan, he announced, could be calculated as being 13 million miles from the Sun, with an orbit of 20 days and a diameter of 1,000 miles.

But that was the only time Vulcan ever was "seen." There is no question now that there is no such planet.

But Lescarbault saw something. He was not a fraud, but an earnest amateur astronomer who simply made a mistake. The best guess is that he saw a sunspot.

So Mercury remains the innermost of the planets—and

both the hottest and the coldest. No planet is as hot as the sunward side of Mercury. No planet is as cold as its dark side. Even Pluto, more than 3.5 billion miles out from the Sun, is warmer.

And life, you ask?

The chance of there being any life on Mercury is so fantastically small it is scarcely worth considering. No place more hostile to life can be imagined.

One cannot say positively, of course, that no virus, no extremely simple form of life, can possibly exist—for it is just barely conceivable they could.

But not very likely.

9.

Venus: What Have We Here?

ON NOVEMBER 28, 1959, A HIGH ALTITUDE BALLOON lifted from the famed Stratobowl, scene of many other famous flights, near Rapid City, South Dakota.

Aboard it were two men, a 16-inch Schmidt camera and a spectrograph.

The mission of the two men aboard—Commander Malcolm D. Ross, veteran naval balloonist and physicist, and Charles B. Moore, Jr., of Arthur D. Little, Inc., Cambridge, Massachusetts—was to determine whether the planet Venus had water vapor in its atmosphere.

Venus is our nearest planetary neighbor, at times approaching within 25 million miles of us. But we know less about it than we do about any other planet, with the possible exception of Pluto. This is because its face is eternally

shrouded by a heavy cloud cover which we have never been able to penetrate.

Unable to see the surface, not even knowing the speed of the planet's rotation upon its axis, we can do little beyond studying the clouds in which Venus hides itself. From a study of these clouds we may gain some clues as to the situation on the surface.

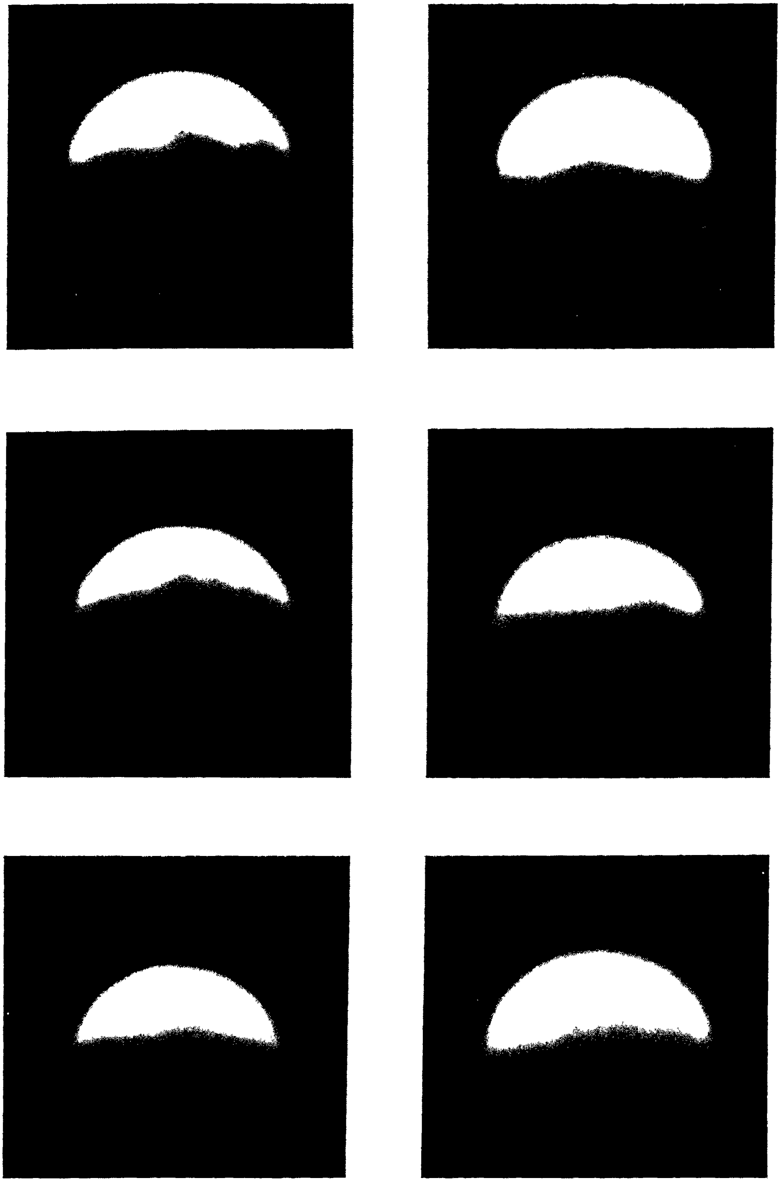
Analysis of the clouds show large amounts of carbon dioxide and nothing else—which doesn't mean, of course, that there *is* nothing else. Kozyrev, the Russian astronomer who believes he caught a volcano erupting on the Moon, announced recently that he had found some evidence of the presence of nitrogen on Venus; but his findings have not been confirmed.

Many attempts had been made, prior to the flight of the research balloon in 1959, to determine if water vapor existed in Venus' atmosphere. If water vapor existed, then certainly oxygen also was present. If this were the case, we then would have information which might enable us to dig a little further into the mystery of the planet.

But to detect water vapor in an analysis made from the surface of the Earth was next to impossible. The stumbling block was that Earth's own atmosphere is so filled with water vapor it is difficult, if not impossible, to separate out the probable evidence of water vapor in Venus' atmosphere from the overwhelming evidence of water vapor in our own atmosphere.

To find out if water vapor existed on Venus, one would have to get above Earth's atmosphere—or above the greater part of it.

This is exactly what Ross and Moore did on that November day of 1959. They took a spectrograph and telescope (a Schmidt camera is a telescope designed for picture taking) to some 81,000 feet above the Earth, where little or no



Venus photographed with the 100-inch telescope. (Mount Wilson and Palomar Observatories)

Earthly water vapor exists. At this height the Schmidt camera was trained on Venus, with the spectrographic apparatus tied into the scope. The spectrograph analyzed the light from Venus picked up by the telescope and recorded the analysis of that light on film strips.

Dr. John Strong, director of the Laboratory of Astrophysics and Meteorology at John Hopkins University, who had planned the expedition, studied the film after it was brought back to Earth. He found strong indication of the existence of water vapor in Venus' atmosphere in the recordings on the film.

The finding, at the moment, is not completely confirmed; but it does give good reason to suspect that part of Venus' clouds are made up of water vapor and that, therefore, one can expect oxygen also to be present. The spectrographic analysis, however, gives no indication of the amount of water vapor there may be in the clouds.

The evidence of the presence of water vapor on Venus at once gave rise to renewed speculation that life may be found there. For water and oxygen are the two basic requirements of life as we know it.

But no sooner had a few scientists proclaimed the possibility of life on Venus than others stepped forward to knock the idea in the head.

Two of these were Dr. Robert H. Menzel, director of the Harvard College Observatory, and Dr. Fred L. Whipple, head of the Smithsonian Astronomical Observatory. The surface of Venus, they speculated, is possibly an ocean of boiling carbonated water—or, if you would rather, soda pop.

Venus, they pointed out, is closer to the Sun than is the Earth, and therefore receives more of the Sun's heat. Furthermore, the heavy percentage of carbon dioxide in the planet's atmosphere would create a "greenhouse effect" which they calculated would raise the temperature at the surface of the planet to well above the boiling point of water.

A "greenhouse effect" involves the trapping of heat. In a greenhouse, the glass allows the Sun's warmth to enter, but hinders it when it attempts to get out. The heat thus is accumulated in the greenhouse—a steady heat, which is necessary for the growing of plants.

Perhaps you have gotten into an automobile which has been standing in the sunlight on a summer day with all the windows closed. The inside of the car is warmer than the air outside. On an extremely warm day, the interior of the car may be so hot you can barely grasp the steering wheel. This is an example of the greenhouse effect. The heat had gotten in, but couldn't get out.

Glass, however, is not the only thing which traps heat. Carbon dioxide does the same thing by absorbing infra-red radiation, which is heat. On Earth the carbon dioxide in the atmosphere traps the heat during the day and prevents its rapid loss during the night, when the Sun is no longer in the sky. If it were not for this carbon dioxide action, the night side of the Earth would lose virtually all the heat it had built up during the day—and lose it rapidly.

Only three hundredths of one percent of Earth's atmosphere is composed of carbon dioxide. If this much carbon dioxide can keep the night side of the Earth from cooling off too rapidly or too much, we only can imagine what effect the much greater amounts of carbon dioxide in the atmosphere of Venus would have on the surface of that planet.

If the percentage of carbon dioxide in Earth's atmosphere were doubled, the average temperature of the Earth would go up three degrees. If it were cut by half we'd have a new ice age.

The Earth is, in effect, a greenhouse, with carbon dioxide playing the part of glass.

Fear has been expressed by some scientists that man may be adding to the carbon dioxide in the air, and in time may increase the greenhouse effect, warming up the Earth. By

burning fossil fuels (coal, oil, gas) we are releasing great amounts of carbon dioxide into our atmosphere. There are other factors, too, which would serve to increase the carbon dioxide content; but the burning of fossil fuels is the most important.

The Earth, however, has a built-in safety valve which, given time, will regulate the amount of carbon dioxide in the air, keeping it in balance. This safety valve is the ocean. The oceans are great absorbers of carbon dioxide and eventually will soak up whatever additional carbon dioxide we may be pumping out from our industrial centers and our homes.

The question is not: Will the oceans absorb it? but rather, Will they absorb it fast enough?

A good deal of data has been obtained in recent investigations of this very question; but so far there is no clear-cut answer.

This business of more carbon dioxide in our atmosphere is no joking matter. We are in for some rather startling and disastrous developments if the amount of carbon dioxide in the atmosphere is increasing.

Even a rise of three degrees, which we mentioned as resulting should the carbon dioxide in the atmosphere be doubled, would melt all the ice in the world. As was pointed out in an earlier chapter, should this happen, much of the eastern seaboard of the United States would be flooded.

Any appreciable warming up of the Earth, whether through an increased greenhouse effect or for some other reason, would move the so-called lines of equal temperature north and south on either side of the equator. In all likelihood, the lines of equal rainfall would move with them. Texas and the southern part of California would become deserts. Flowers would bloom in Greenland, and wheat could be grown as far north as the Arctic circle.

It is believed that an increase or decrease in the carbon dioxide in Earth's atmosphere may have accounted for the great climatic changes which we know have occurred on Earth in past ages. It may be that a decrease in the carbon dioxide content may have brought about the great ice ages, by lowering the average temperature. But we can't be sure of this. There are so many factors involved in our climatic picture that it's impossible to put one's finger on any one of them as a specific cause for any of the changes.

While this has nothing to do with Venus, it does show the importance of the carbon dioxide in that planet's atmosphere.

Menzel and Whipple, in their hypothesis as to the kind of world Venus may be, assumed that Venus was completely covered by water. This water would be boiling, because of the high surface temperature, and carbonated, because of the high concentration of carbon dioxide in the atmosphere. Remember what was said about an ocean being a good absorber of carbon dioxide.

Carbon dioxide, in case you have been wondering, is the stuff that puts the bubbles in your bottle of pop.

Menzel's and Whipple's contention that Venus must be a hot planet gained almost immediate confirmation from Dr. Frank Drake of the National Radio Astronomy Laboratory at Green Bank, West Virginia.

Drake said that radio emissions picked up from the planet by the observatory indicate that the surface temperature is 585° Fahrenheit, well above the boiling point of water.

The heat of a planet produces radio signals of a certain frequency, which can be picked up by sensitive radio telescopes. The people at Green Bank, Drake said, have been training their telescopes on Venus, off and on, ever since 1956. There is, he said, no doubt about the temperature. It is—or at least it has been ever since 1956—585 degrees.

The heat, Drake theorizes, is due either to a hot central core or to the greenhouse effect.

He does not go along with Menzel and Whipple on their ocean theory. The temperature, he explains, is too high for water to exist in liquid form. Under such heat, all water would boil away, would never have a chance to condense. If it ever did condense and start to fall as rain, it would be turned to vapor again as soon as it approached the surface of the planet. Whatever water there may be on Venus, Drake says, would be water vapor, a part of the planet's atmosphere.

If you'll think back, you'll recall that this is exactly the sort of situation that may have existed on the Earth in its very early days.

Under such conditions, Drake contends, it is highly unlikely that life of any sort could exist on that planet. The surface of Venus, he believes, consists of barren rocks and desert.

Because Venus is our nearest neighbor, and because we know so little of it, no other planet has been the subject of so many theories.

When it was first determined that Venus was continually wrapped in a great cloud cover, it was believed that the clouds must be very much like the clouds of Earth. The apparent thickness of the clouds, then, meant that Venus was a world of water.

Thus there arose the classic idea of a Carboniferous Venus.

The Carboniferous Period was an age upon the Earth, some 250 million years ago, when the world, a few places excepted, was one great marsh, with a heavy growth of lush vegetation, and with the first amphibians crawling through the dank and dripping landscape. It was during the Carboniferous period that the Earth's deposits of coal and oil were laid down for our later use.

When the early search for water vapor on Venus failed, ideas about the planet changed. If there were no water vapor, then Venus must be a world entirely without water. A new picture of Venus was constructed—an image of a dessicated world without a drop of water, swept by terrible dust storms beneath a sky so filled with heavy clouds that there was never actual daylight, but at best a sort of grimy twilight.

In the theory of a Carboniferous Venus, there had been hope of life. But in this new theory of Venus, there was no hope at all.

These were both early theories and very simple ones—perhaps too simple, for the factors that go to make up the conditions on any planet are very seldom simple.

There are many more theories—some of them are so fantastic as to be ridiculous. But there are others that make a lot of sense.

One of these is that hydrocarbons were present in greater quantities than water, on primeval Venus—the Venus of several billion years ago. What water there was, says this theory, combined with the hydrocarbons to produce carbon dioxide, until all the water was used up. As a result, the surface of Venus now is covered with what is left of the hydrocarbons—and there is likely to be a lot of it.

The hydrocarbons would be most likely to take the form of petroleum; so we are left with a picture of Venus covered by a sloshing sea of oil. The cloud cover, under these conditions, might largely be composed of smog.

And, despite the evidence against it, the theory of Venus as a world of water—one great sea, with no land anywhere—continues to hold out.

There is one thing wrong with all of this, of course: At best, we're only guessing. The guesses, necessarily, are very educated guesses, but they have only the barest facts to go on. For in our analyzing of the planet's atmosphere, we're not

analyzing the entire atmosphere, but only the upper layer of it. Just how deep the atmosphere may be there is no way of knowing.

One of the puzzles of the Venusian atmosphere is its brilliance and apparent whiteness. We say apparent whiteness, for it actually has a rather pronounced lemon color. Sometimes the yellow is more pronounced than at other times.

The reason for the variation in color of the atmosphere seems to be that the top-most clouds are white, while the dense, underlying clouds are yellow. At times, apparently, the upper clouds are broken, revealing the yellow underneath more prominently than is usually the case. There is speculation that the yellow clouds may be gigantic dust storms kicked up by the fierce surface winds.

The brilliance of the top cloud cover is a bit too bright for ordinary atmospheric gases. For this reason, it is believed that these clouds may be composed of quartz crystals or ice crystals, either of which would have a high degree of reflectivity.

Near the apparent poles of the planet are what seem to be even brighter protruding features sticking up out of the atmosphere. The theory has been advanced that these might be high mountains, higher than anything that we know on Earth. But this theory has been largely discounted, because the mountains would have to rise at least 36 miles high, and perhaps a great deal higher. There must be, it is now felt, another explanation for this phenomenon.

At the beginning of the last paragraph we used the phrase, "apparent poles." We did this because scientists are not sure where the poles of Venus are. It has been presumed that they correspond to the poles of Earth; but we can't be sure.

Darker cloud bands are seen on the planet when it is

photographed in ultra-violet light. They are not spectacular. You and I might even be hard-put to find them. But to astronomers, they are most significant, and they have been studied closely.

The bands, at times, maintain their positions for weeks; but they are not permanent. At one time it was thought that they were surface features showing through the clouds; but now it's known that they're not—that we have never seen anything on the surface of Venus.

It is believed the bands may be caused by the circulation patterns in the atmosphere. Kozyrev, of Russia, believes they may be caused by massive molecules—or, rather, by lots of massive molecules. If this is true, the dark bands may be places in the atmosphere where the unknown molecules are clustered. There is, as yet, no clue as to what kind of molecules they may be—if, in fact, an unknown molecule is involved at all.

The one basic puzzle which has concerned scientists for years is the great amount of carbon dioxide found in the atmosphere—far more than any self-respecting planet should ever think of having. The very fact that we find so much carbon dioxide present is one of the arguments which has been advanced to prove that no water can exist on Venus.

With water present, carbon dioxide would react with silicates to form limestone or sand. If water were present, it could be expected that most of the carbon dioxide, in time, would have become fixed in rocks. At best, only a small amount would be left over for the atmosphere.

One neat explanation, as mentioned earlier, would be that Venus is covered by one vast ocean. If this were the case, there would be no surface rocks to absorb the carbon dioxide. As a result, the atmosphere would be loaded with it.

But if Venus is as hot as the Green Bank people say it

is, then the idea of a Venus entirely covered by water would seem to be impossible.

So we're back just where we started. It seems that every time you dream up a good idea to explain something about Venus, someone comes along and proves that you are wrong.

As you may by now have guessed, the list of things we do not know about Venus is so long as to be embarrassing. Some of them, for example, are very simple things—like the period of the planet's rotation upon its axis, or the direction in which the axis is pointed.

If Venus had permanent markings, determining its period of rotation would be an easy job. You'd only have to time the rotation of one of the markings to find the speed of its rotation. But the few dark blotches that occasionally are seen on Venus are worthless for this purpose, since they are not permanent.

By measuring what is known as the Doppler effect, which involves the shifting of the spectral lines seen in the spectrograph, it should be possible to measure the rotation. But evidently Venus is rotating so slowly that measurement by the Doppler effect fails to work. The shift in the lines is so small that any measurement made of them is subject to inaccuracy.

But there is a strange situation here. In 1903, Dr. V. M. Slipher, of the Lowell Observatory in Arizona, made Doppler measurements of Venus. He came up with the conclusion that Venus was rotating in a retograde direction.

This means that if you were looking down on Venus from over its north pole (presuming that Venus' north pole is in the same position as the Earth's), Venus would be spinning in a clockwise motion. This is a contradiction to the general rule in the solar system. All the other planets spin in a counterclockwise direction. That is, they spin in the direction opposite to that taken by the hands of a clock.

In 1924, the measurements were repeated by St. John and Nicholson, a famous team of astronomers at Mount Wilson. Again the answer came up that Venus was rotating in a retrograde direction.

In 1958, Dr. R. S. Richardson, at Palomar Observatory, also got results indicating a retrograde rotation for Venus.

All of these astronomers were reluctant to accept their results, because it just doesn't seem logical that Venus should be rotating in a direction opposite to that of all its neighbors. Whatever the force that originally sent the planets spinning in a certain direction, it should have acted equally upon all of them. Venus should be no exception.

Richardson, in his measurement for rotation, got a rotational period of fourteen days—that is, he found that Venus rotates once upon its axis every fourteen Earth days, rotating just once while the Earth rotates fourteen times. Similar results were obtained by Slipher in 1903, and by the Mount Wilson astronomers in 1924. But because of the apparent slowness of the spin, the measurements enter such a hazy area that none of the four observers made any claim to accuracy. In fact, in each instance, they pointed out the wide chance of error.

A study of radio signals, resulting from some unknown action within the planet's atmosphere, gives a result of twenty-two hours, seventeen minutes as the rotational period.

But this rate seems to be too high. If Venus were spinning that fast, it would tend to bulge at the equator and flatten at the poles. This is true in the case of the Earth, with a spin of twenty-four hours. But no evidence has been found of any bulge or any flattening on Venus. Earth is oblate, like an orange. Venus appears to be round, like a ball.

However, since everything about Venus forms a mass of contradictions, it is only fitting and proper that one piece of evidence does point toward a rapid spin. Heat measurements

of the cloud cover on both the day and the night side of Venus give essentially the same temperature. By rights, the night side should be far colder than the day side. A rapid rotation, however, would give the night side less time to cool off, and the temperature of the two sides would remain about the same—as is the case. If the axial spin should really be as slow as fourteen days, the temperature on the night side would be bound to drop drastically, unless there were strong atmospheric currents to carry the warmth from the day side around to the night side, and thus keep the atmosphere equally heated. But there is no evidence, and no reason to believe, that there are such currents.

All through this chapter we have been telling what we do *not* know about Venus and speculating upon certain probabilities, about none of which we can be very certain.

So what *do* we know about Venus? Well, a few things; not very much.

We know it is 67 million miles from the Sun, as compared to Earth's 93 million miles from the Sun. We know that it travels around the Sun in a few hours less than 225 days. We know that it has a diameter of 7,700 miles, as compared with a diameter of 7,918 miles for the Earth. Its mass is about 82 percent that of the mass of Earth—that is, it "weighs" about 18 percent less than Earth. Its gravity is 88 percent that of Earth's gravity. If you weigh 100 pounds on Earth, you'd weigh only 88 pounds on Venus.

And that, when we get right down to facts, is about all we do know about Venus.

Often Earth and Venus are described as sister planets, because they are so similar in many respects. But these similarities are only apparent. Once you get beneath the clouds, they're about as different as you can imagine.

And the ancient question: Is there life?

Bearing in mind that we can speak of life only as we

know it, it would seem impossible that life could exist on such a planet.

The heat alone—close to 600 degrees—would be enough, all by itself, to make life impossible. The great preponderance of carbon dioxide, and the possibility that there may be no oxygen, would make animal life impossible. Plants, however, could live in an atmosphere heavily weighted with carbon dioxide. For plant life, just the opposite of animal life, lives on carbon dioxide and releases oxygen as a waste material.

But plants also need water; and whether Venus has water is still an open question. Say, however, for the sake of argument, that there is water, and that the plants could somehow have adapted to the excessive heat. Even then there still is reason to believe that no plants grow on Venus. If there were plants, in the millions of years they had existed they would have used up large quantities of the carbon dioxide. They would have sucked in millions upon millions of tons of it, and perhaps have laid it down in great coal beds and oil fields, such as were laid down during the Carboniferous age on Earth. If there were plants on Venus, one could logically expect that it would have a far different atmosphere than it has today.

The best guess is that life never got a start on Venus, as it did on Earth. The most probable reason for this would be the lack of water—although there may have been, as well, a hundred other reasons.

It is interesting to speculate (for the pure fun of the speculation) what kind of "people" might have arisen on Venus if life had developed there and if that life had advanced to intelligence.

They would be, to start with, a people without stars, and thus a people without any knowledge of the universe. And without a knowledge of the universe, they would remain forever ignorant of many of the laws of Nature.

At times, when the cloud cover lightened slightly, they might get a glimpse of a brilliance shining through the clouds; but they would never see the Sun directly. They would probably never know there was such a thing as the Sun. Their nights would be pitch black, and they'd never see the stars, would never guess there were such things as stars.

They would be puzzled, probably, by the coming of the light and the fall of night. They'd not know the reason for it. They would have no idea of the solar system and would know nothing of the mechanics which makes it operate.

They probably would dream up some sort of explanation of where they were and what might lie beyond. They might have fanciful explanations of why the light came and why the darkness fell. But these explanations would have no scientific basis.

They'd never develop the telescope, nor, perhaps, lenses of any sort, for they'd have no need of them. Aviation would not develop, for flying would be impossible in the murky cloud cover that would press down upon the surface. Surveying might be an unknown art, since it would be virtually impossible to establish lines of latitude and longitude; and there'd be no maps.

But this, you understand, is speculation and nothing more. For it is most unlikely that there is any life, let alone intelligence, upon our nearest neighbor.

But when we say there is no life upon Venus, we do not necessarily mean there never will be life upon the planet.

Man someday may engineer the planet so that life will be possible. And when that happens, the people of the Earth will have a brand new world to use—perhaps in riper wisdom than we've used this world of ours.

To make Venus livable for humans, four things must be done.

We must get rid of most of the carbon dioxide in the atmosphere.

We must lower the temperature.

We must provide some water.

We must have some oxygen.

Dr. Carl Sagan, of the University of California, has suggested a way in which these things might be done.

He proposes that spaceships flying above the atmosphere seed the clouds of Venus with tiny plants, such as the blue-green algae. Such plants, he believes, might survive in the cooler upper air. The plants, if they lived, would exist by the normal processes of photosynthesis. They could make use of the water vapor in the atmosphere to convert carbon dioxide into plant tissue, releasing water and oxygen in the process.

It would be an engineering job that might take thousands of years; but if the algae could live in the atmosphere, in time it would bring about many drastic changes.

It would eventually use up a great part of the carbon dioxide in Venus' atmosphere. With the carbon dioxide largely used up, the greenhouse effect would be decreased, and the planet would cool off. With the planet cooled, the water vapor could condense and fall as rain, and there would be water on the planet's surface. As the carbon dioxide was used up, free oxygen would build up.

In time it would be possible for the algae to live, not only in the atmosphere of Venus, but on the surface as well. And when that happened, we would be almost ready for man to drop down from the skies and claim Venus as his own.

It would take a lot of algae seeding and a lot of patience —and it might not work. There might be a lot of reasons why it wouldn't work.

But if it did, it would be worth the waiting.

It's not every day that man can pick up, dirt cheap, his very next-door planet.

10.

Earth: The Old Home Planet

THE THIRD PLANET OUT FROM THE SUN IS ONE THAT we know well—but not half so well as we think we do. Earth is still largely unexplored. Not its surface, of course, for by now there are few areas where man at some time has not placed his foot. But its ocean bottoms still are comparatively unknown. We have begun, in just the last few years, the task of exploring its atmosphere. Its interior is still, in large part, a mystery.

If the Earth is represented as an orange, we know the outer skin, and that is all.

Earth is a very special planet, since it is our home. But just how special we cannot realize until we study it and see how each part of it and each feature of it interacts, one with another, to make possible the kind of situation which not only tolerates, but supports life.

If the Earth were different, but not so different as to make life impossible, then you and I would be different sorts of creatures. We are, by and large, what the Earth has made us. We have adapted to our planet.

Earth probably is the only planet in the solar system which has large amounts of liquid water. Whether it is possible for water to exist on Venus is a moot question, as we have seen. Mars probably has some water, but nowhere near the amount that Earth has. But aside from Earth, Venus, and Mars, no planet has liquid water, though there may be great amounts of it frozen on the dark side of Mercury. If Pluto has any water, it, likewise, is frozen.

The presence of large amounts of liquid water on Earth is of great importance to us. Many scientists are beginning to believe that water is even more basic to animal life than is oxygen. Life, as we know it, either plant or animal, could not exist without water.

About 70 percent of our planet's surface is covered by water. About 10 percent is covered by ice. Taken all together, this totals out to approximately 350 million cubic miles of water.

If there were such creatures as intelligent Martians, they probably would consider Earth as impossibly wet—perhaps to the point of being unlivable. To them, accustomed to the dryness of their native planet, the waters of the Earth would be terrifying.

But while our water is important, our atmosphere is equally so. It is a unique atmosphere, unlike any other in the solar system.

We think of fish living in the waters, whereas we live on what we commonly call dry land. But, actually, we're not so different from fish; for we live in an element of our own as surely as they do in theirs.

The atmosphere is our "sea" and without it, there'd be no

life on Earth. Take that atmosphere away from us even briefly and we die as surely as the fish which is taken from the water.

Without an atmosphere, there would be no weather nor any of the manifestations of weather—no clouds, no rain, no wind.

Without an atmosphere, fire would be impossible, since there'd be no oxygen. There would be no such thing as sound, for sound is nothing more than vibrations within the atmosphere. There'd be no sky, blue or otherwise, for we'd look out directly into the black of space. Harmful short-wave radiations, such as the ultra-violet, would come pouring in directly from the Sun, with not a thing to stop them. Even if life were possible without air to breathe, these unshielded radiations would be deadly to all life. Without an atmosphere, we'd be exposed directly to the heat of the Sun; and when the Sun was gone, we'd be exposed as directly to the cold of space. Out of this space would come, unhindered by any atmosphere, thousands upon thousands of meteorites, pounding down upon the surface, making it, in a few years time, as pocked as is the Moon.

This, then, is our atmosphere. It supplies us with the air we breathe, it protects us from the fury of the Sun and the cold of outer space. It gives us the medium in which we can live and move and perform our feeble wonders.

And for all its seeming simplicity, it is one of the most complex mechanisms man has ever known.

Meteorologists regard it as a heat engine in which the energy of the Sun is turned into mechanical motion. This mechanical motion is the circulation of the atmosphere, which, in turn, provides our weather.

Solar radiation, coming in from the Sun, strikes the atmosphere. Some of it is absorbed by water vapor and carbon dioxide. Some of it is absorbed by oxygen molecules to produce ozone. Radiation which reaches the surface is absorbed either by the soil or by water or by vegetation.

Water vapor ranks high as a storer of the energy which reaches Earth form the Sun. It takes a good deal of energy to make water boil; likewise it takes a great deal to make water evaporate—about half a million calories to turn one quart of water into vapor.

Some of the radiation (mostly visible light) which reaches the surface, rather than being absorbed, may be reflected back into the atmosphere again. Bright water surfaces, a sheet of tin, shiny vegetation—all of these reflect light back into the atmosphere.

In addition to reflecting some of the light back into the atmosphere, the surface also will radiate, as a sort of continuous exchange, some of the energy which it has absorbed. Any substance which has a temperature higher than its surroundings will radiate energy to these surroundings. Therefore, when the surface has reached a temperature warmer than that of the immediate atmosphere, it radiates energy in the form of heat radiation. As these heat radiations are fed back into the atmosphere and travel back up through the atmosphere, some of them are absorbed by water vapor and carbon dioxide.

Thus we have a continuing energy exchange, involving the Earth itself, the Earth's atmosphere and the space above and outside of Earth's atmosphere. Energy comes in from the Sun and is absorbed either by the Earth or the atmosphere. Other energy is radiated out into space. Inasmuch as we know that the temperature of the Earth and its atmosphere doesn't change a great deal from one year to another, we must assume that the energy exchange is in balance.

But we do know that geographically the absorption of the energy is unequal. From the tropics to the middle latitudes, more solar radiation is absorbed than is lost by reradiation. From the middle latitudes to the poles, more radiation is lost than is received. It is the attempt of the atmosphere to equalize this uneven energy distribution that gives

us wind and weather. The net warming in the tropics and the net cooling in the polar regions sets up the global atmospheric circulation.

This is true not only of the atmosphere, but of the oceans as well. Ocean water is warmed by sunlight in the tropics, and is cooled in the polar regions by melting ice and snow and by the radiation of energy back into space. Cold water in the polar regions sinks and makes its way toward the tropics, flowing along the bottom of the great oceanic basins. As it reaches the tropics, it displaces the warmer water, pushing it, eventually, into the polar regions.

Thus the oceans have a general circulation which bears some similarity to the circulation of the atmosphere. Taken all together, the oceans and the atmosphere form a great engine which is driven by the energy put out by the Sun. And it is the work of this massive and complicated heat engine which makes our world the kind of world it is.

When geophysicists talk about this absorption and loss of energy they call it the heat-budget of the Earth.

Once man realized, a few years ago, that the way to space was open, he began a really serious study of the atmosphere. Balloons carried instruments aloft. Rockets speared up miles above the surface to record conditions there. Satellites were sent spinning into orbit, each with its load of detecting and recording mechanisms.

As a result, today we know, in general, (and in some instances in great detail) what lies between the surface of the Earth and the edge of space.

The atmosphere is no simple thing. It is not just one great mass of gases. It is a complicated combination of many layers, each with definite characteristics.

The lower layer of the atmosphere, called the troposphere, and extending some 4 miles above the surface at the poles and 10 miles above the surface at the equator, is that

part of the atmosphere we know. Within it is concentrated, by quantity, most of the gases represented in the entire atmosphere.

Above the troposphere is the stratosphere, which contains the ozone layer. In the ozone layer, oxygen molecules are formed of three atoms, rather than the two atoms of a molecule of the common oxygen with which we are acquainted. It is this three-atom oxygen, called ozone, which screens out the ultra-violet radiation.

The ozone layer is a very thin layer and occupies only a small segment of the stratosphere.

Above the stratosphere is the ionosphere, so called because much of the gas which it contains is ionized. Within the ionosphere are the F-layers, which bounce back radio signals, making radio transmission possible.

About 75 percent of the atmospheric gases are in the troposphere, not quite 25 percent in the stratosphere. The ionosphere contains approximately one three-thousandths of one percent. And in the exosphere, which extends above the stratosphere, the density is only a trillionth of that at ground-level. The ionosphere is considered a fairly good vacuum; the exosphere is a part of the atmosphere by not much more than courtesy.

The stratosphere extends from the troposphere to a height of about 60 miles, while the ionosphere goes up to around 400 miles. The exosphere then begins and extends out into space. Within these main layers of the atmosphere are a number of other layers which are parts of the main layers, each with slightly different characteristics.

Only a few years ago not too much was known about our atmosphere; but with the beginning of the space age, we've been amassing a truly wondrous file of data on it. Much of this data was not available until the space age started, and we had the rockets and the satellites which could

go above the Earth and gather the information for us. There's still much that is not understood. It will take years of study before we know the atmosphere as well as we know land.

When we do, there'll be the advantage of knowing not only answers which will aid us in going into space, but also answers that will help us to understand much more about our weather.

But it's not only to the heights above that man is turning his attention. He also is looking to the depths below.

The Mohole Project is aimed at drilling a hole deep into the Earth, down to the level of what is known as the Mohorovicic discontinuity, called Moho for short. If we were to drill from the surface of the Earth to reach the Moho, we'd have to go down at least 20 to 25 miles. But by drilling at sea, we will have to go through only 6 miles or less of crust. This is because the crust of the Earth is much shallower below the oceans than it is beneath the continents.

But before we tackle the Moho, perhaps we should back up a notch and take a look at what we know of the interior of the Earth.

The crust, which is that portion of the Earth which we walk upon and which extends for varying depths into the interior, is composed of basalt under the ocean beds and of granite under the continents.

Granite is a kind of rock with which we're all acquainted. It is the commonest rock there is. And while a piece of it is heavy to lift, it is classed as a light rock. Basalt is heavier, but is still classed as a light rock. As a matter of fact, basalt and granite, because of their lightness, float on the surface of the other rocks of which the Earth is composed.

In this particular case, the term "float" is just slightly tricky. The granite and the basalt do not bob around like a piece of wood does on the surface of a pond. But they do

float. For the rock of the mantle, which lies beneath the crust, actually is a fluid.

The basalt and the granite, in ages past, apparently floated up to the surface of the planet, exactly as lighter materials float to the surface of a body of water and form a scum. This process of the granite floating to the surface probably took many centuries.

The Earth's crust varies in thickness. Beneath high mountains or plateaus it extends for 25 to 30 miles, with "roots" at times extending even deeper. It is strange to think of mountains as having roots, but in fact they do. Under less elevated land, the crust is not so thick. In places under the ocean beds it is only 5 to 6 miles deep.

The continents appear to float on the mantle on exactly the same principle as an iceberg floating in water. The higher the berg sticks out of the water, the deeper it lies in the water.

When a mass of ice floats in water, one-ninth of it is above the surface, while eight-ninths is submerged. The same holds true for the continental masses, except that here the ratio is six to one instead of nine to one. Roughly, for every foot that a continental mass extends above sea level, five feet extends down into the mantle.

The mantle of the Earth lies beneath the crust and extends downward for a distance of 1,860 miles. The best evidence is that it is composed of olivine, a rock of olive-green color, rich in magnesium and iron. At a glance (although no one has ever glanced at it), it probably would appear to be solid rock. Actually, it is believed, it is an extremely thick fluid, very much like pitch, but thicker than pitch. And while it is incredibly strong, it is able to adjust over the years to any shifting of the crust.

The Mohorovicic discontinuity is the boundary line

between the crust and the mantle, marking a sharp division between two kinds of rock.

The discontinuity is named after Andrija Mohorovicic, a professor at the University of Zagreb in Serbia, now Yugoslavia. In 1909, Mohorovicic was studying the records of earthquake waves, which is the main way in which we learn about the interior of the Earth. His study convinced him that a definite boundary existed between the crust of the Earth and the mantle. Subsequent investigations proved his theory, and the boundary came to be known as the Mohorovicic discontinuity.

And in case you're wondering, the pronunciation of Mohorovicic is Moe-hoe-roe-veech-ic, with a very slight accent on the next to the last syllable. You'll be doing all right, however, if you forget the accent.

The density of the rock builds up rapidly in the mantle. At the Mohorovicic discontinuity the density is about 3.3 times that of water. But by the time the mantle extends down to the outer core, the density is 5.5 times that of water. The average density of the crust, for comparison, is 3 times that of water.

At the edge of the outer core, the density suddenly jumps to 9.5 and builds up to 11.5 at the bottom of the outer core, which extends down some 1,300 miles. Eleven times the density of water represents a rigidity four times greater than that of steel.

At the center of the inner core—that is, at the center of the Earth—the density may be 18 times the density of water. The pressure at the center of the Earth is figured at four million atmospheres. Since atmospheric pressure at the surface of the Earth is 15 pounds per square inch, this works out to a pressure of around 60 million pounds per square inch at the center of the Earth. The temperature there is believed to be in the neighborhood of 11,000° Fahrenheit.

The core is generally supposed to be made up of iron or nickel iron. But more than likely it is no such iron or nickel iron as man has ever known. For under a pressure of 60 million pounds per square inch and a temperature of 11,000 degrees, the metal would be in either a plastic or a liquid state—and a liquid or a plastic compressed and squeezed together beyond anything we can imagine.

Almost all the knowledge that we have at the moment concerning the nature of Earth's interior has been gained from our study of earthquake waves. The waves change their speed and characteristics as they travel through different layers and materials of different natures. From this, the scientist can make deductions as to the kind and condition of the different rocks which make up the body of our planet.

But if we could drill down through the crust to reach the mantle, then we would be dealing with actual observation. From the cores brought up by the drill we could learn many things—perhaps some things we do not now anticipate.

One thing we might learn more about is the age of the Earth. So far, the oldest rocks found have been dated at an age of about three billion years. Yet we're absolutely certain that Earth is older than that. Perhaps there are no rocks at the surface which are older than three billion years. But by drilling into the interior of the Earth, we may find older ones.

Rocks are dated by the progress noted in the disintegration of radioactive elements. Radioactive materials of different kinds break down at a steady rate. By reckoning how far this breakdown has progressed, we can calculate how much time has elapsed since these radioactive "clocks" were wound up and set to running.

By analyzing the sediment piled on top of the crust on the ocean floor, we probably could learn much about the history of our oceans. As you may recall, the oceans did not appear immediately when Earth was formed. It probably

was untold centuries before the waters of the Earth ran together to form our seas.

Also, traces of the earliest life on Earth might be found in the deepest oceanic sediments, revealing something more than we know now about the history of evolution.

By drilling deep into the crust, we may gain more evidence on the Earth's internal heat. We know that in deep holes drilled in the continental masses heat increases as the hole goes down. But the Mohole, once the drill bites into the basalt crust beneath the seas, will be closer to the center of the Earth than the deepest hole on the land.

The prime objective of the project, of course, is to reach the Moho itself and to drill a short way into the mantle, thus determining what kind of material constitutes the mantle. But as the drill sinks toward the Moho, the cores brought up along the way will give us other bits of information which we have not yet been able to lay our hands upon.

Drill tests already have been made to try out the equipment. One of these days the Mohole will be drilled, and man will have probed into another dimension of his planet.

It probably will be necessary to drill a number of holes at different localities before an average sampling of the mantle is obtained. But the first sample taken from that first hole will give us some idea of what we may expect to find.

The Mohole Project is sponsored by the National Academy of Sciences, with the Navy and many other governmental agencies cooperating.

While man is exploring the atmosphere and making ready to drill through the thick hide of his planet, projects also are going forward for a wider study of the sea.

On January 23, 1960, the bathyscaph "Trieste," in a dive sponsored by the United States Navy, reached the depth of 35,800 feet, the bottom of the Challenger Deep in the Marianas Trench off the coast of Guam. The depth worked

out to almost 7 miles; the vessel reached the bottom of what is believed to be the deepest hole in any of Earth's oceans.

In the bathyscaph to make the dive were Lieutenant Don Walsh, of the Navy, and Jacques Piccard, son of Auguste Piccard, inventor of the bathyscaph.

A bathyscaph is a strange contraption. It is neither a submarine nor a diving bell. Rather, it is a balloon in reverse. Instead of rising in the air, it is designed to sink into the sea. It has no power of its own and its gondola, which is the great steel ball carrying the passengers and instruments, must be strong enough to hold up under the tremendous pressures found at the great depths beneath the sea. The pressure was close to eight tons per square inch at the bottom of the Challenger Deep.

In a balloon, bouyancy—the ability to float up through the air—is gained by dropping sand ballast to lighten the balloon. When the bouyancy is too great and the balloon rises too rapidly, or when it is time to come down, gas can be released from the bag.

The same principle works in the bathyscaph, except that gasoline, contained in a great float, is used to provide bouyancy. Gases would be useless as a bouyant agent at sea bottom pressure. Iron pellets are used as ballast. When the shot is dumped, the bouyancy of the gasoline raises the gondola to the surface.

The bathyscaph probably will, in time, become the basis of a device which can be used for the study of the ocean and its floor.

We may expect to see new deep-sea ships whose design will overcome some of the shortcomings of the bathyscaph. These deep-sea ships probably will be able to operate on their own power and to move about freely on the ocean floor. The cramped quarters of the bathyscaph gondola are a disadvantage, and undoubtedly some way will be found to pro-

vide more room for both instruments and men and yet keep the structure strong enough to stand up under the pressures of the ocean depths.

During the International Geophysical Year (IGY for short), an intensive study was made of the oceans; and under a continuation of the year, the work still is going on. Now under way is a thorough-going study of the Indian Ocean, the first step in a more detailed investigation of the world's oceans.

Not only was a study of the oceans carried on during IGY, but so were studies of all the other features of the Earth. Billions of pieces of data were collected, many of which still await evaluation. Some rather astounding discoveries were made; but the principle value was that the Year (called a year despite the fact it ran for eighteen months, from July 1, 1957 to December 31, 1958) laid the basis for continuing research, and placed an emphasis upon the gains which might be realized from the study of our planet. The IGY was an adventure into understanding such as the world had never known. It was a planet-wide co-operative venture in which sixty-six nations took part, with some sixty thousand research men involved.

One of the more fantastic of the IGY discoveries concerned the shape of the Earth.

For years it had been assumed that the Earth was an oblate sphere, meaning that it was somewhat squashed in at the poles and slightly bulged at the Equator. And, of course, that assumption still stands; but some important frills have been added to it.

The Earth's mean (average) diameter is 7,917.78 miles, making the mean circumference work out to 24,874 miles. But the actual diameter varies. From pole to pole, through the axis of the planet, it measures 7,900 miles; through the Equator, 7,927 miles. The reason for this equatorial bulge is

centrifugal force caused by the rotational spin of the planet.

In March, 1958, the United States launched Vanguard I, known as the "grapefruit satellite" because of its size.

Dr. Ann Bailey (then Ann Eckels), working at the Vanguard Computation Center in Washington, was engaged in plotting the orbit of the satellite. She noted a startling thing —an unexplained rise and fall in the satellite's orbit. The orbit seemed to be saying that the northern hemisphere of the Earth was bigger than the southern hemisphere. And that was absolutely impossible, for then the Earth's center of gravity would be out of kilter.

Puzzled, she took the orbital figures to Dr. John O'Keefe, assistant director of the theoretical division of the National Aeronautics and Space Administration. Together, the two of them checked over the computations. Ann Bailey was right —something about the Earth was entirely out of whack.

There could be one explanation, O'Keefe suggested. The Earth could be a pear-shaped planet.

Once again the figures were checked and rechecked. The mathematics said that O'Keefe's idea was correct—the Earth definitely was pear-shaped.

This pear-shape takes a bit of explaining. It means that the North Pole is higher by some 40 feet than had been assumed. The South Pole is a corresponding 40 feet lower. A 20-foot depression and a 20-foot bulge run, respectively, around the northern and southern middle latitudes. Which means there is a little more bulge south of the Equator than north of it.

The figures are so small that you'd never notice the difference just standing off in space and looking at the Earth. It still would be orange-shaped—an oblate sphere. But take these figures and multiply them about 100,000 times and you get a pear-shaped Earth.

The implications of the pear-shaped Earth are interesting and important.

For some time prior to the discovery by O'Keefe and Mrs. Bailey, there had been a tendency to think of the Earth's mantle as being so plastic it barely had the strength to hold together. If this were so, the Earth was a singularly unstable planet, barely able to hold up under its own gravity.

But the finding that such an irregularity as the concept of the pear-shaped Earth could exist means that the Earth does have far more mechanical strength that was previously believed. Which means that it is entirely stable and that we need have no fear it will become unstuck.

All too often we take this planet of ours for granted. It is an old and familiar thing. It seems that it has always been here, although now we know it hasn't. It seems it will always be here, although now we know that in some future day there will be no Earth. And it seems, at first thought, that we must know most of what there is to know about it. But now we realize that there still is much to learn.

And as man digs into the job of learning about his own planet, he undoubtedly will find certain facts which will enable him to explain some of the mysteries of the other planets.

Likewise, when he goes to the other planets, he will find things there which will aid in his understanding of our Earth.

11.

Mars: An Old Friend of Ours

MARS IS AN EXASPERATING PLANET. THERE IS NO BODY in the solar system, other than our own planet and its moon, about which we know so much; and yet, knowing all of this, there is little about Mars that we understand.

Mars swarms with apparent mysteries—which, of course, are no mysteries at all, and only appear so because we do not understand them. The chances are that once we get to Mars, the truth about these mysteries will be so logical and simple that we'll wonder why we didn't think of them.

And because of the very fact that we know so much of Mars and yet understand so little, it is the most intriguing planet in the entire system.

Aside from the usual statistics, we know this much about Mars: It has a thin atmosphere; there are polar caps that form each fall and disappear each spring; there are seasons on the

planet; there are changes in its physical features; the planet has a changeable climate; probably it has weather.

And, what is more important, there is a fairly good chance that it has life of some sort. Not monsters, not people, not even animals, but probably vegetation. It's not a sure thing, you understand, but there's a fairly good chance that we'll find life when we reach Mars.

Mars revolves at a distance of 141.5 million from the Sun, and at its nearest approach to Earth comes within some 34 million miles of us. On September 7, 1956, Mars swung to within 35,131,000 miles of Earth. This was the closest it had been since 1924. It will not come as close again until 1971.

Mars is only slightly more than half the size of Earth. Its diameter is 4,216 miles. The length of its day is almost identical with ours: It turns on its axis once each twenty-four hours, thirty-seven minutes. Since it has farther to go than Earth, however, its year (one revolution around the Sun) lasts 687 days, not quite twice as long as ours.

It has two tiny moons—perhaps the most fantastic moons in the solar system. Deimos, the outer moon, orbits 14,600 miles above the Martian surface. It is only slightly more than 5 miles in diameter. Phobos, the inner moon, is about 10 miles in diameter, and lies in an orbit 5,800 miles out from Mars.

Deimos makes a complete circuit of Mars in about thirty hours, so that it travels around its planet five times each four days. Phobos makes three complete orbits around Mars each day.

I. S. Shklovsky, the Russian physicist and mathematician, has suggested that Phobos and Deimos are not actually moons, but satellites fired into orbit many years ago. Though he does not say so, the assumption naturally would be that an intelligent race of beings lived on Mars at the time the "satellites" were put into orbit.

Shklovsky's speculation is based on the fact that the

Martian moons are the tiniest in the solar system, and that their rapid movement is almost unbelievable. Nor do any other moons lie so close to their parent planets.

Shklovsky's observations show that Phobos appears to be falling in closer to Mars. The Russian predicts that in another fifteen million years it will crash upon the planet.

But whether natural moons or satellites put up by a long dead race, Deimos and Phobos may be of considerable aid when the time comes for man to explore Mars. Either would make a handy base of operations. An expedition ship could land on one of them and a camp could be set up there, with explorers using smaller, lighter ships to shuttle between the moon and the planet. This would make unnecessary the great expenditure of fuel which would otherwise be required to lift a heavy ship off the Martian surface when it was time for the Earthmen to go home again.

A great deal has been written in science fiction about the exploration of Mars; and in many instances, the planet has been represented as fairly similar to Earth. Men have been made to breathe its air and to walk around without the need of spacesuits. But actually, this would not be the case.

The Martian atmosphere is not something you could breathe—not because it's poisonous, but because it is too thin. Likewise, it probably has little oxygen. At one time there may have been a great deal of oxygen in the atmosphere of Mars; but the best evidence is that most of the primitive oxygen now is locked up in chemical combination with the surface rocks.

It is likely that the Martian atmosphere is composed of nitrogen, carbon dioxide and possibly argon. There is no detectable trace of water vapor or of oxygen, although both probably are present in minute quantities. It is unlikely, however, that there is more than one-thousandth as much oxygen in the Martian atmosphere as there is in Earth's.

The atmospheric pressure on Mars is computed at one

fifteenth that on Earth—one pound per square inch instead of fifteen pounds. And that, if nothing else, should give you some idea of how thin the atmosphere is. In other words, the density of the atmosphere on the Martian surface is about the same as the density of Earth's atmosphere at the height of 11 miles.

And despite the fact that we're almost certain there is some water on Mars (we'll get around later to the reason for this belief) it is there in such small quantities that the air is extremely dry. Even were it otherwise possible to breathe the Martian air (and certainly it wouldn't be), the very dryness of the air would make it impossible. One breath of that air and the mucous linings in our lungs, throat and nose would be burned beyond repair—the air having sucked out every bit of moisture from them.

So don't be fooled, no matter what the stories say. If you ever go to Mars, you'll wear, if not a spacesuit, at least a breathing apparatus—and be glad of it.

Nor is the climate of Mars the kind an Earthman would select. On the equator, the temperature gets up to around 50° Fahrenheit, at noon. But at night it falls to —90°. And this, incidentally, would be the most favorable temperature range. At the poles the noon temperature wouldn't go as high as 50°, and the temperature would drop much lower than —90° once the Sun had set.

This sudden drop in temperature is explained by the fact that the thin, dry air of Mars is unable to retain the heat soaked up during the daylight hours. While there is some evidence that Mars may have clouds, they could not be anywhere near as heavy as the clouds of Earth, which help to hold in heat. Nor has Mars any greenhouse effect, such as we have on Earth. As soon as the Sun goes down, the heat is lost and the temperature nose-dives.

We won't have as much trouble with gravity on Mars

as we will on the Moon, where the pull of gravity is one-sixth what it is on Earth. Martian gravity is 37 percent of that on Earth. Walking might be a little tricky for a while, but we'd soon get used to it.

So, provided with a tank of air and, perhaps, some sort of clothing to protect him from the moisture-sucking dryness, an explorer on Mars will get along all right. He'll have to have a good warm shelter to duck into as soon as the Sun has set; but otherwise he should stay fairly comfortable.

When anyone says "Mars," the first thing that is apt to pop into one's mind are the canals.

Actually the word "canals" is a bit of an unintentional boner, so let's set the record straight.

Our old friend, Schiaparelli, the Italian astronomer, was one of the first men who saw (or thought he saw) the network of lines on Mars which have since come to be called the canals.

Schiaparelli, writing in Italian, called this network of lines *canali*. In Italian, that means channels. When his work was translated into English, the word *canali* became "canals" instead of channels. And since canals are artificial waterways, the public (and some people who should have known better) immediately speculated that the canals had been dug by an intelligent race. The idea of artificial canals tied in beautifully with the known lack of water on Mars; for even then we knew that the planet was deficient in water. What could be more reasonable than that a dying race, as a last desperate move, built the canals to channel down from the poles the last water on the planet?

So the myth sprang up full-blown. There are canals on Mars. Canals are dug only by an intelligent people. Therefore there must be, or must at one time have been, an intelligent race of beings on Mars.

It has taken years to make the public realize that the

canals probably are not the work of an intelligence, but rather, if they exist at all, just an ordinary surface feature. We can't positively rule out, of course, the possibility that they are actually canals; but the chances are very high that they aren't.

Astronomers are distinctly of two minds about the canals. There are some who have seen them and are convinced they actually exist. There are others who have never seen them and are equally convinced there are no such things. The latter are certain that their colleagues who have seen the canals have suffered optical illusions—not an unlikely occurrence when one is working with a telescope. And there have been astronomers who had never seen the canals and were sure they did not exist, but who finally did see them and are now ardent believers in them.

There seems to be, in the balance, rather more evidence that the canals do exist than that they don't. The fact that they have been seen by some men and not by others probably means nothing more than that those who have spotted them have been lucky enough to catch a good "seeing" night. There are nights, when conditions are just right, that Mars swarms with distinct markings. At other times, barely anything can be made out.

Even among astronomers, in the earlier years of this century, there were some who emphatically believed that the canals were just that—great ditches dug to carry Martian water. These men pointed to the straightness of the canals as evidence that they were artificial. Nothing could occur in nature, they contended, which would continue along a straight line for hundreds of miles. Furthermore, they pointed out, the canals seem to be set in a geometric pattern. They lead straight as arrows from one area to another, they intersect at certain points, groups of them meet and merge. Could these

points where they merge, perhaps, be the sites of Martian cities?

But this thinking now has largely, if not entirely, been abandoned. Today's astronomers, in fact, are not too concerned with the canals. More than likely they are bored with them. After all, the pesky things have been around for years and no one has learned a single thing about them. After a time such a situation gets discouraging.

In addition to the older canal explanations, many other possible ideas have been advanced to explain the Martian network of lines. One suggested explanation—that the canals are a result of meteorite falls—suffers from the fact that no straight-line falls of such great extent can be found on the Moon. Certainly meteorites would not fall in one way on Mars and in a different way on the Moon. It has been suggested that the canals may be ancient river beds; that they are volcanic in origin; or that they are great cracks caused by the shrinking of the planet.

Another proposal is that they are trails made by great migratory game herds traveling from one water hole, or one salt lick, to another. But this explanation runs up against the near certainty that it would be impossible for any kind of large animal to survive on Mars. And even if they did exist, water holes would be few and very far between if there were any at all.

Still another theory which has been advanced is that the canals may be roofed-in ditches built by an intelligent race to seal in the little that is left of the planet's atmosphere and water, perhaps by the use of pumps to build up the atmospheric pressure. This is a sort of refinement of the canal idea—incorporating the atmosphere with the water and providing a roof as well as a channel. The theory's proponents point out that a network of roofed-in canals would not coop

the Martians up as lone sealed atmospheric centers would, but would give them easy access to the greater part of their planet.

Evidence that the canals depend, to some extent, upon the Martian season is provided by the fact that they first appear about the first of the Martian April. By mid-June (Martian mid-June, that is) there is little left of them. Only a small portion of the network can be seen during the Martian autumn and winter. In this way they parallel the Martian maria, which we'll get around to in another paragraph or two.

Whatever the canals may be, they are large. While they appear to human observers as only faint, thin lines, to be seen at all they have to be massive things, many miles across.

More interesting than the canals are the maria, the dark areas which, like similar dark regions on the Moon, were at one time thought to be seas and were so named.

There is now going on a highly argumentative controversy concerning the maria. One school of thought inclines to the belief the maria are areas of vegetation. Another school argues that they are carpets of volcanic dust swept into shape by the faint winds of Mars.

Whatever they may be, the maria do change with the seasons. Like the canals, they darken and become more prominent about the first of the Martian April, fade in mid-June, and can be barely seen in the autumn and winter.

This change of color and the fact that they change shape and spread in the spring are the main bases of the contention that they are areas of vegetation.

With the coming of each spring, the maria near the polar cap darken and this darkening spreads toward the equator, traveling at the rate of about 30 miles a day. The natural inference is that moisture from the melting polar cap is spreading down across the face of Mars, bringing the dormant vegetation to life as it flows.

There is one catch to this.

The polar cap is a prominent feature of Mars. It lies there, white as snow or ice would be, and it covers a wide area. But all evidence indicates that this covering of snow or ice must be very thin. In all likelihood, it is not more than an inch thick. It may be, actually, an accumulation of hoarfrost rather than ice or snow.

If this is so—if the polar cap is only an inch or two thick—it could not possibly store water enough to seep down across the face of Mars.

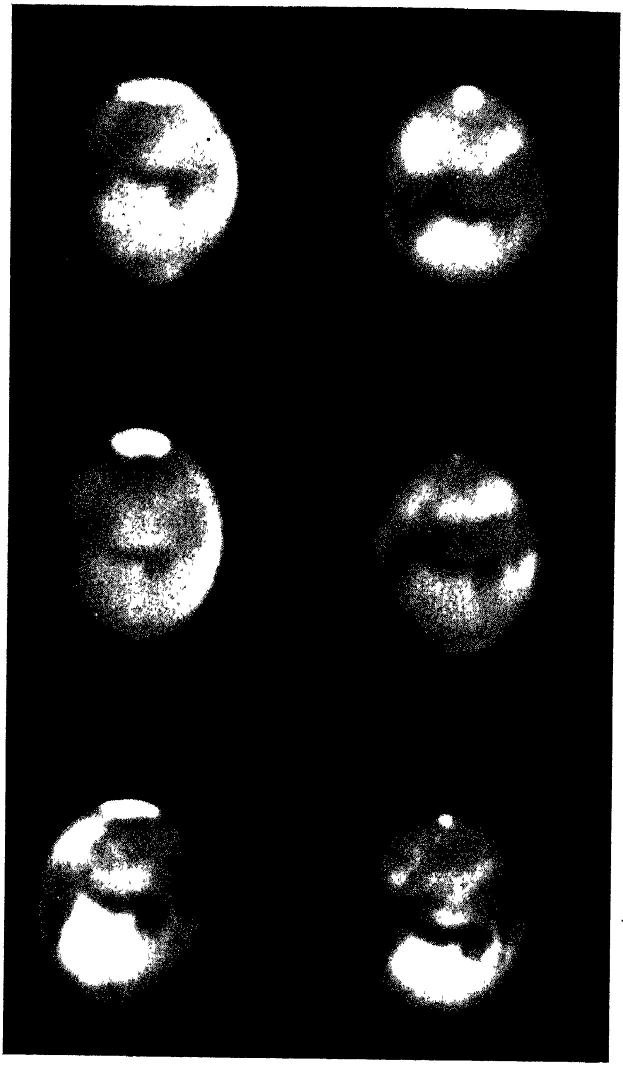
It is even doubtful that in the thin Martian atmosphere much actual melting would occur. The disappearance of the polar cap with the coming of each spring is much more likely to be caused by evaporation than it is by melting.

But that, of course, is the way things are on Mars. You never get a straight answer. You never can explain a thing without something popping up to contradict your answer. Like Venus, Mars is a mass of contradiction. But it is ten times worse than Venus, because it is a planet about which we know so much more than we do about Venus. And of all the things we know, not a single one will ever come out right. Mars is, without a doubt, the most exasperating planet a man can come across. Everything about it looks incredibly simple, then turns out to be incredibly complex. There is no end to the ways in which it can pester you.

The fact seems to be that there is not enough water on all of Mars to nourish vast areas of vegetation. There seems to be no way that water can be transported on Mars except by circulation, as vapor, through the atmosphere.

And yet each spring, when the polar cap disappears (we won't say that it melts), great areas of the Martian surface darken, exactly as if some sort of vegetation were springing back to life.

Because of the water problem, many astronomers have



**April 7* *June 2*

May 10 *July 31*

April 29 *July 10*

Mars photographed in its Spring and Summer, showing melting of South snow caps and striking seasonal development of dark markings in the tropics. (See doubling of dark bands across center.) (E. C. Slipher, Lowell Observatory)

* *The Mars dates given here correspond to our calendar dates in the Northern Hemisphere.*

sought an inorganic rather than an organic explanation for the maria.

One such explanation is that they are great lava fields which periodically become covered with dust—thus accounting for the darkening and dimming. And yet it is hard to understand how all the dust is swept off the lava fields early in each Martian April to allow the darker lava to show through. Or why this great sweeping process should continue equatorwards at a steady 30 miles a day. Or why, in the middle of June, the dust should begin to sift back again, and finally, in late summer, should again hide the lava from our view.

And even if we did concede that such a natural sweeping and re-covering process was somehow possible, there still would be another question: If the maria were lava, then they would be one color, year in, year out, fifty years ago and fifty years from now. But the maria do change color. One year they may have a greenish cast, another year they will be a bluish gray. Or at times they may have a touch of brown.

Some astronomers have suggested a sort of compromise. They suggest that the maria may be lava covered in part by a very hardy vegetation—perhaps some sort of lichen. But this doesn't seem to help too much. It solves none of the problems. It does no more, in fact, than combine the problems of both the vegetation and the lava theories.

Few astronomers of late have been more concerned with the mysteries of Mars than has R. S. Richardson. In 1956 he rigged up what looked as if it might be a sure-fire test to determine whether the maria were made up of vegetation. Well, maybe not vegetation, exactly, but chlorophyll-bearing plants.

Chlorophyll reflects red light poorly. If, using a red filter, you take a picture of a foliage-covered tree, the leaves

will come out black. This is because the chlorophyll in the leaves reflects little red light.

Chlorophyll, incidentally, does reflect green fairly well, and thus leaves and grass look green to us.

But while chlorophyll reflects red light very poorly, go a bit deeper into the red end of the spectrum and the situation changes. Infra-red is reflected powerfully by green leaves and grass. We don't see this, of course, because we can't see into the infra-red range. But use an infra-red filter to take a picture of a tree, and the tree will look as if it were covered with snow. This is because the chlorophyll bounces back the infra-red and washes out the film.

Richardson reasoned that if the maria were formed of vegetation, and he took a photograph of them in red light, the maria would turn out darker than they appear in ordinary light. But if he took a picture in infra-red light, and the maria were composed of vegetation, the maria then would turn out bright.

So he took the pictures. And there was no difference between them. The maria were neither darker nor lighter than they had ever been.

This would mean, then, that if the maria are made up of vegetation, the vegetation is different from the ordinary chlorophyll-bearing plants of Earth.

But it doesn't rule out the existence of vegetation; for there are plants on Earth which reflect light to about the same degree throughout the entire spectrum. The principal examples of this sort of plant are the lichens.

Lichens are a crazy sort of plant, just the kind of thing you'd expect to find under the harsh conditions on the Martian surface. On Earth, you find them everywhere.

Actually, a lichen is a combination of two plants—a fungus and an alga. The two live in a partnership which is beneficial to both. The alga, through its photosynthetic proc-

ess, supplies food for both itself and the fungus, which has no photosynthetic apparatus. In return, the fungus protects the alga from harm and provides it with shelter.

Lichens are tough customers. The harshest environment Earth can offer has no terror for them. They are found on rocks below the snow line on mountain tops. They have been found, living happily, on rock outcroppings in the polar regions. And they can be found, growing sturdily, on desert rocks which at noon become too hot to put your hand upon.

They are long-lived things. Colonies have been estimated to be more than two thousand years old and still going strong. They grow very slowly and need little food. They can withstand long sieges of adverse conditions—in fact, they seem to glory in their ability to survive almost anything.

If you were to pick out, from all Earth's vegetation, the one plant that would best survive on Mars, you'd probably pick the lichen.

But all this doesn't mean that lichens grow on Mars. At best it means they probably *could* grow there, and that they were not eliminated from consideration by the Richardson photographs.

There is one other angle to consider so far as Martian vegetation is concerned.

Light reflected from any Earthly vegetation, when photographed through a spectrograph, shows absorption bands at 3.41 and 3.51 microns. What that means, briefly, is that certain readings are found at certain points on the light spectrum scale when light reflected from Earthly plants is analyzed.

Light from the maria of Mars, when broken down by the spectrograph, shows three readings: at 2.43, 3.56 and 3.67 microns.

This is not, as you can see, a duplication of the result

one gets on Earthly vegetation. But it is close enough to make one suspect that the light may have been reflected from vegetation which may be somewhat different from Earth's vegetation.

It is significant that light reflected from the lighter areas of Mars, which we presume to be deserts, shows no such readings.

Just how vegetation on Mars could differ from that on Earth is not known, of course. But one could suspect that the molecules which make up the vegetation could be slightly different from the molecules we find in our own leaves and flowers. Different, but still making up a type of vegetation. It may be that certain differences in the conditions on the two planets have brought about a difference in the molecules which make up vegetation.

One of the pieces of evidence which supports the belief that the Martian maria may be composed of vegetation is that the areas change from year to year. Some shrink, some get larger; whole new areas appear, spreading rapidly. And this simply doesn't square with the lichen theory, for Earth's lichens are the slowest-growing things we know. If a lichen patch on Earth grows an inch in ten years it is moving at a gallop.

Too, the Martian maria seem to be fairly solid. If it is vegetation we are seeing, it is a thick crop of vegetation, covering all the ground. Earth lichens are shy. You find them here and there—a patch of them on a rock, another patch upon a tree. It seems most unlikely that Earth's lichens ever would cover any great area of land.

And there's yet another thing. We know that there are dust storms on Mars, for they have been observed many times: heavy yellowish clouds blowing across the surface. In certain instances portions of the maria apparently have been covered by dust from such a storm. And yet, in a short

while the dark areas have recovered and are back again, exactly as before.

The only explanation one can think of is that the vegetation had grown through the layer of dust. It is just short of absurd to think that a layer of dust deposited on a specific surface would have blown away again, freeing that precise area, in just a few weeks time.

In fact, in view of the dust storms, it would be reasonable to suppose that in the millions of years in which Mars has existed in its present state, the winds would have made a dust world out of it. All the irregularities should have been smoothed out by the deposits of dust or sand. By this time, surely, Mars should have become perfectly smooth, with a uniform surface tint. This becomes even more likely when one considers that Mars appears to have no mountains. It is a land of flat, far plains or deserts and of rolling hills.

But Mars is not a dust world. There are both the maria and the canals. There is some speculation that no distinction can be made between these two—that the canals are merely creepers put out by the maria, exactly as a strawberry plant in a garden puts out creepers every year.

We have been talking all this time about vegetation; and that is a bit misleading, perhaps. In view of the situation, what we might better say is "some sort of life." The lichens of Earth come the closest to what we conjure up when we try to imagine what sort of life might be possible on Mars. But there are certain specifications which do not match those of the lichens.

Any life upon Mars undoubtedly would be based upon the same essentials as is life on Earth. But millions of years of evolution may by now have produced a considerably different kind of life than that we know on Earth.

A number of astronomers and biologists have done a vast amount of research, attempting to duplicate a Martian

environment as a life laboratory, or observing conditions here on Earth which might resemble those on Mars.

Once again it is the Russians who have taken the lead in this. Experiments have been carried on by Russian scientists on the Pamir Plateau. Except for the greater air pressure and the higher percentage of oxygen, conditions there are much the same as those we imagine must exist on Mars. It is as cold as it is on Mars, and the air is extremely dry.

One of the things which the experiments proved was that plants growing in extremely cold climates do not reflect as much light as those growing in warm climates. The colder it gets, the less light the plants reflect. What happens is that they soak up more of the light than do plants in warm climates.

This may explain, in part, the failure of Richardson's attempt to detect Martian chlorophyll by taking pictures in the red and infra-red ranges. But it is unlikely that it explains the failure in its entirety.

The Russian experiments showed also that a great variety of plants are able to withstand extreme cold—cold as great as anything that Mars may have to offer. Nor did the dryness of the Pamir seem to have an adverse effect upon the experimental plants.

The Russian astronomer Tikhov points out that the Pamir plants, soaking up the infra-red for heat, reflects more light in the blue than do plants in warmer climates. This means that the plants appear darker than those in temperate or tropical zones. He speculates that the coldness of Mars may account for the darkness and bluish color of the supposed Martian vegetation.

Proof that certain types of Earth life could exist on Mars was supplied by an experiment carried out at Randolph Air Force Base in Texas, by the Department of Microbiology, United States Air Force School of Aviation Medicine.

The experiment involved the duplication of a Martian atmosphere and climate within a "Mars jar." Red sandstone and lava soil was placed in the bottom of the jar. This soil was then inoculated with soil micro-organisms (bacteria found in the soil). After ten months it was found that certain types of bacteria had disappeared. They had been killed off by the simulated Martian conditions. But other types not only had survived but had increased in number.

This does not prove, of course, that Mars has life, even in the form of bacteria. But it does seem to demonstrate that life would be possible on Mars, and that certain types of Earth bacteria would flourish there.

And there the case seems to rest.

Life of some sort apparently would be possible on Mars, but we can't as yet be sure it's there. There is strong evidence that the dark areas on Mars may be life of some sort. But final proof of the existence of such life has not been obtained. There are, one must admit, some rather telling arguments against the whole idea.

Another Martian mystery involves what is known as the "blue mist."

When Mars is photographed in red or yellow light, the markings on the surface show up well. But photographed in either blue or violet light, the surface is a blank, with none of the markings except the polar cap showing up.

This is exactly opposite to the situation in photographing Venus. There, red or yellow light shows nothing, but blue light shows up the shifting darker areas which appear in the cloud surface.

Red light, which has a longer wave length than blue, is more penetrating than blue light is. Blue light, with a short wave length, is more easily scattered by molecules of air. Every camera fan knows that he can get a clear picture of

distant objects if he uses a red filter, but that a blue filter washes out the background.

The difficulty of photographing Mars in blue light would be understandable if it held true at all times. But it does not. Occasionally the blue mist clears away, and pictures taken in blue light show surface features almost as clearly as do those taken in red. The clearing may last for several nights or only for a few hours. It can extend over the entire face of the planet or over only one small area of it.

If Mars had an ozone layer such as Earth has, to shield its surface from ultra-violet radiation, the blue mist would make some sense. For if an ozone layer shields out the ultra-violet light, one could expect it also would shield out blue light.

But ozone is derived from oxygen. Ordinary oxygen molecules are made up of two atoms of oxygen. An ozone molecule is made up of three atoms of oxygen. And on Mars, where would the oxygen come from to form the ozone? The fact that an ozone layer on Mars seems impossible means either that some agency other than ozone protects the hypothetical Martian life from the ultra-violet rays, or that Martian life has built up a resistance to ultra-violet and has learned to live with it.

Ruling out the possibility that the blue mist is really ozone, it has been speculated that the mist may be formed of fine dust particles or tiny ice crystals of frozen carbon dioxide. A mist made up of either of these materials would break up the short wave length of blue light.

But if the mist does consist of these substances, what happens, occasionally, to clear the Martian atmosphere?

A good deal has been made of the fact that the clearing of the blue mist always occurs when Mars is "in opposition"—that is, when it is closest to the Earth. But Mars' position may have nothing to do with it. Mars is very seldom studied by

astronomers except during the time it is the closest to us. If it should be studied when it was at a greater distance, instances of the clearing of the mist might be found then also.

There has been a suggestion that the clearing may occur when Mars, the Earth and the Sun are in a straight line. The idea is that the Earth's magnetic fields might then distort the Sun's radiation in such a manner as to affect the light falling on Mars, and thus bring about the clearing. But this is a theory only, with no evidence to support it.

One Martian feature, other than the polar cap, which does photograph well in blue light is one type of cloud. These are the white, wispy clouds which apparently float high in the atmosphere of Mars. Occasionally, but not too often, these clouds cover a good part of the planet. They probably are made of ice crystals floating twenty miles or more above the surface.

The other type of cloud is yellow and appears to be only a short distance above the surface. Clouds of this type are generally believed to consist of blowing dust or sand. Some truly tremendous dust storms, covering a large part of the planet, have been observed.

And there's another kind of cloud—or what was at first thought to be a cloud. The probability is that it is not really a cloud.

In 1954, both Richardson and Dr. E. C. Slipher, of South Africa, sighted a great W marking on the face of the planet, which marking they supposed to be a cloud. It was no small affair. Each stroke of the letter measured about a thousand miles.

Interesting, said the two astronomers, not too much impressed. For clouds, at times, can take on some funny shapes.

But the W was back in 1956, and in 1958. The chances are fantastically small that on three separate occasions, four years apart, clouds should form the same configuration.

Richardson, vastly puzzled, reports that the W had a highly artificial look. As if someone had gone up in a plane and done some massive sky writing.

It's a bit ridiculous to imagine that a cloud formation could become permanent. And no one can guess what sort of surface formation could look like a giant W.

Canals, maria, the blue mist, the giant W—we don't know for certain what any of them are.

12.

The Asteroids: Fragments of a Failure?

MARS LIES 141 MILLION MILES FROM THE SUN. Jupiter, the next planet out from the Sun, is at a distance of 483 million miles from our central star. This means that some 342 million miles lie between Mars and Jupiter. Somewhere in between them there should be a planet. Mercury is 36 million miles from the Sun, Venus 67 million, Earth 93 million. That 342-million-mile jump between Mars and Jupiter is just a mite too empty.

Bode's law, which we explained earlier is actually not a law, says there should be a planet between Mars and Jupiter.

But there is no planet, although at one time there possibly might have been.

Instead of a planet there is what is known as the asteroid belt. Because of this name, an entirely erroneous idea of the belt has been built up. It is thought of too often as a massive

stream of planetoids and other assorted hunks of rock orbiting rather tightly between Mars and Jupiter. It is really no such thing.

Forgetting about the belt entirely, it may be said that the asteroids are small fragments of planetary material which maintain an orbit, roughly, between Mars and Jupiter. Roughly, because some of them have such crazy orbits that they reach inside of Mercury and almost out to Saturn.

The first asteroid was discovered on Jan. 1, 1801, by Giuseppe Piazzi, an Italian monk and astronomer. It was named Ceres and was 450 miles in diameter, the largest of the asteroids. At the moment, some 1,600 have had their orbits computed. Another thousand or so have been listed, but their orbits have not been worked out. It is estimated that there may be 50,000 of them with a diameter down to a mile or so.

It is likely that the belt contains some millions of asteroids of basketball size and up, and uncounted other millions in sizes ranging down to gravel. Plus a lot of sand and tiny bits of rock too small to really count.

As a matter of fact, many of the meteorites which pelt the Earth and the other inner planets are believed to be bits of debris from the asteroid belt.

Not all meteorites, of course, originate within the belt, but a goodly portion of them do.

Probably some of the meteorite material which comes from the belt are the result of collisions between some of the small asteroids. These collisions would break off some pieces of material from the colliding masses and would shoot them off in new orbits which in time might intersect the paths of some of the inner planets.

One thing, probably, which should be emphasized is that, no matter what its size, every bit of material in the belt, even down to the grains of sand, is moving in an orbit of its own.

There is no such thing as random motion in the solar system. Everything that's in it is moving in a definite path forced upon it by gravitational pull of the various other bodies included in the system. Most of this gravitational pull, of course, is occasioned by the Sun.

And if we wish, of course, this same rule can be applied to all the universe. There is nothing that moves at random in the universe. Everything included in it follows certain rules of order set up by celestial mechanics.

Despite the number of hunks of debris included in the belt, it is estimated that the total mass of all this rock and metal, all this sand and gravel, probably is no more than one thousandth that of Earth.

Therefore it is easy to see that the space between Mars and Jupiter would not be filled with debris. While the chunks of matter might show up a little oftener than in the space beyond Jupiter, the chances are that a spaceship could cross from Mars to Jupiter without being in too much danger.

The asteroids which have been listed have all been given names and numbers. Those asteroids which remain in a fairly sane orbit somewhere reasonably between Mars and Jupiter have been given feminine names. There are some lulus among those names—Harmonica, Photographia, Fantasia, Arnica, Limburgia, Geisha. Famous men also are honored by having an asteroid named after them—Hooveria and Rockefellia, for example. In case you're puzzled, that final "a" is supposed to make the name feminine.

But there are certain of the asteroids which are far from well-behaved. They wander far off the beaten track. These are given male names and are known as the "male" asteroids.

We must understand, of course, that each of these male asteroids is following a logical course so far as it itself is concerned. It is obeying the laws of the universe and of the solar

system. But at some time during its history it has been subjected to gravitational pulling and hauling which has forced it into a different orbit than the great mass of asteroids.

Jupiter, the most massive planet in the system, is suspected of most of the shoving around resulting in the eccentric asteroid orbits. It is possible that some of Jupiter's large family of moons may be asteroids which have been captured by the planet and forced to take up an orbit about it.

Some of the roving male asteroids come perilously close to Earth, although the danger that one of them ever will collide with Earth is something like a million to one.

The first asteroid detected as coming within speaking distance of the Earth was Eros, which was discovered in 1898.

Eros is a strange asteroid. While many of the asteroids may not be sphere-shaped, but be simply jagged pieces of rock and metal, there is evidence that Eros is a huge slab of rock tumbling end over end. When first seen in 1898, its diameter was calculated at 17 miles. But when it showed up in 1931 it appeared to be winking—a long, slow wink. It would shine brightly for a couple of hours, then become dimmer, then suddenly would grow bright again. It is believed that as it tumbles end over end, part of the time it exposes a flat surface to the Sun, this flat surface acting as a mirror to make it bright. Then, as the flat side turns away from the Sun, there is less surface to reflect the light and it dims. Its approximate dimensions now have been worked out to be about 17 miles long and four miles wide.

Eros can come as close to us as 13,800,000 miles. In 1975 it will approach this close. In 1931 it passed within 17 million miles of us.

For a long time it was believed that Eros represented the closest that an asteroid would ever come to Earth. But in March, 1932, Amor came within 10 million miles. And scarcely had Amor been listed by the astronomers than along

came Apollo, which rocketed past at 6,500,000 miles. In 1936 Apollo's record was smashed as Adonis came swishing along, a mere 1,300,000 miles away.

But it wasn't ended yet. It almost seemed as if someone were standing out in space, heaving asteroids at us, trying for a bull's-eye. On Oct. 30, 1937 Hermes missed us by just 485,000 miles, less than twice the distance to the Moon.

Astronomers have calculated that Hermes could come as close as 220,000 miles of us, which is closer than the Moon. And that's a slight bit too close for comfort, since Hermes has the diameter of about a mile.

We know where Eros is, for the astronomers had plenty of time to work out his orbit. But Apollo and Adonis came at us too fast and suddenly for us to get a solid fix on them. They're gone now and we have no accurate figures to plot the orbits for them. They may be gone forever. Earth may not for centuries be in a position to cross their orbits again.

Amor we did get enough on to work out an orbit and it was seen again in 1940. Having gone past the Earth, Amor continues to plunge past Venus and comes within 59 million miles of the Sun before it curves back into outer space again.

The most interesting of the male asteroids is Icarus, discovered in 1949. Its orbit carries it inward past Mercury and to within 19 million miles of the Sun before it retreats out into the outer reaches of the system again. In 1950 and again in 1952, Icarus went bumbling past Earth on its way inward toward the Sun and now its orbit is known as well as any body in the solar system.

When it reaches its closest approach to the Sun, it must glow white hot. When farthest from the Sun it must be utterly frozen.

Icarus is named after the youth of Greek mythology who attached wings to his body with wax and was able to fly—perhaps the first man to ever fly in any story. But in his pride

he flew so close to the Sun that the heat melted the wax. His wings dropped off and he fell into the sea.

Another interesting, and highly suspect, asteroid is Hidalgo. Moving in a 14-year orbit, it goes out at its farthest beyond the orbit of Saturn. For years astronomers had a suspicion that it was no asteroid, but a comet. Its elongated orbit was far more like that of a comet than an asteroid. But after years of study no other cometary features were discovered and it is now tagged as an asteroid, although a mighty strange one.

It might be that there would be many more asteroids than there are were it not for Jupiter. The big planet, with its massive gravitational field, must act as the vacuum cleaner of the asteroid belt. Any small, slow moving asteroid that gets close enough to the planet to feel the clutches of its gravity must eventually plunge to rest within the mystery of Jupiter's cloudiness. Failing to suck an asteroid in, Jupiter will wrest them from their orbits and send them off on other paths.

But there are two groups of asteroids which live at peace with Jupiter. One cluster is traveling about 60 degrees ahead of the planet and the other cluster 60 degrees behind. Remembering that the circle described by Jupiter's orbit measures 360 degrees, as all circles do, you can easily figure out the exact position of these clusters, which are called the Trojan clusters.

Yes, I know I've said, and truly, that the orbits of the planets are not circles—but the 360 degrees still stand in figuring out the position of the Trojan clusters.

The clusters are traveling squarely in Jupiter's orbit, one of them trailing him and the other breaking trail. The reason they can maintain this position lies in the problem of three bodies.

The solution of this problem (which has been very neatly

solved by the Trojan clusters) involves mathematics too complicated to attempt an explanation. The essence of the whole situation is that Jupiter and the clusters are "in balance." If you make a chart of the solar system and draw lines from Jupiter and the clusters to the Sun, you'll find each group forms an equilateral triangle with Jupiter and the Sun. In other words, each cluster is as far from Jupiter as they and Jupiter are distant from the Sun.

There has been speculation that Mars and Earth and maybe even Venus also might have their Trojan clusters. The same celestial mechanics would work with these planets as well as they do with Jupiter. Just recently some inconclusive evidence of what may be Earth's Trojan clusters has been found. But there is no evidence at the moment with respect to either Mars or Venus. And the evidence concerning Earth and its Trojan clusters is far from proved.

All the time, as you've read along, you've probably been wondering about the origin of the asteroids.

There are two probable explanations—one a bit more probable, actually, than the other. And it's a pity, really. For the least probable of the two is the most exciting.

For a long time the idea was fairly well accepted that at one time, billions of years ago, there had been a planet between Jupiter and Mars. And that something happened to destroy the planet, with the resulting debris forming the asteroid belt. According to this theory, the asteroids are all that are left of the fifth planet from the Sun.

The theory was that the planet probably had been about the size of Mars and that it was a terran planet—the same kind of planet as Earth, Mars, Venus and Mercury, formed of stone and metal. For there are two kinds of planets. We'll get to the second kind when we move out to Jupiter.

You'll remember that scientists now estimate that the

total mass of the asteroids probably is not more than one thousandth of the mass of Earth. But this discrepancy could be explained without too much trouble by the wide scattering of the debris, the fall of much of it as meteorites on the inner planets and by the vacuum cleaning job that is done by Jupiter. Jupiter is entirely capable of swallowing a dozen planets the size of Earth without even gulping.

If meteorites come in large part from the junk heap of the asteroid belt, and there is every reason to believe they do, then we have further support for the belief that at one time a planet between Mars and Jupiter may have met destruction. Meteorites come in two types—stony and metallic. The terran planets have metallic cores and stony mantles covering these cores—so the meteorites are just what you'd expect if a planet had been torn apart.

The fact that what apparently is organic material has been found in some meteorites also points to a possible planetary origin. No life, of course, can now exist upon the asteroids. They are so small and their gravity so low that it would be impossible for them to hold an atmosphere of any sort. Ceres, the largest of them, has a diameter of less than 500 miles.

Without an atmosphere, they're naked out in space. They would be exposed to the cold of space and to all the radiations which are moving through space. Any water which might at one time have been on their surface would either be frozen solid or long since disappeared. Under conditions such as this life would be impossible.

But if they are what is left of a one-time planet, there is a possibility that some sort of life may have risen on that planet. If such were the case, it is reasonable to expect that some trace of organic substances might still exist upon the shattered pieces of the planet.

There was one great stumbling block to the theory that

a planet had at one time been destroyed to give rise to the asteroids. No one could think of a really satisfactory manner in which a planet might be destroyed.

One theory was that it might have been destroyed by collision with some other massive body. Still another was that, lacking mechanical strength, it could have been torn apart by that old villain, Jupiter. And a dozen others, all very much less likely. But none of them stood up under critical examination.

Then one day a bomb exploded over a city in Japan called Hiroshima and there the answer was. The fifth planet of the solar system had been blown apart by a nuclear explosion.

The idea captured the popular imagination. For if a nuclear explosion had destroyed the planet, then it must mean that an intelligent race had risen there—intelligent enough to develop nuclear energy, foolish enough to let it get out of hand. In addition to the dramatic appeal of such a notion, it also pointed a powerful object lesson for the people of the Earth. If one planet had been destroyed by nuclear energy, a second one could be and we had better watch our step.

But on more sober reflection, even the public saw that the idea was just a bit too pat and a whole lot more dramatic than good sense would allow. And, anyhow, as more became known of nuclear energy, it was hard to see how a big enough explosion could be set off to tear a world apart. Kill off most of the people, maybe. Kill off all life, even, by poisoning the oceans and the atmosphere—that also would be entirely possible. But to break up a planet—that would be most unlikely.

So once again we were back where we started. Unless we were willing to accept the idea of parallel intellectual evolution on another planet just two removed from us, unless we were willing to believe a nuclear explosion could be engineered to blow up a planet, we had no explanation.

Of late, however, a new theory has been advanced.

The theory says there never was a planet. At the time the solar system formed, the material which should have formed a planet between Mars and Jupiter was there. A planet, perhaps, was scheduled to be there—scheduled by those celestial mechanics of which we have been talking. A planet should have formed, but didn't. Something happened to prevent its forming. Just what could have happened, no one has the least idea.

The asteroids, this theory says, is what was left behind when a planet failed of birth.

You can take your choice, of course. There may have been a planet that somehow was destroyed. But the best explanation seems to be that there was a planet which never could get started.

13.

Meteorites: Things Out of the Sky

THERE ARE FEW PEOPLE WHO READ THIS WHO HAVE not seen a "shooting star." Sometimes it is called a "falling star." But no matter what you call it, it is not a star. It is a meteor.

Perhaps we should, at the outset, try to get the correct terms sorted out.

A meteorite is a mass of solid matter which is either traveling in space or has finally landed on some surface—the surface of the Earth or the Moon or Mars or some other planet. It can be almost any size, from less than the bulk of a grain of sand up to measurements of a mile or two in diameter. A meteor is this same meteorite as it streaks through an atmosphere, where friction raises its temperature to a point where it can be seen as a streak of light. To put it a bit more scientifically, a meteor is the light phenomenon which

is produced by the passage of a meteorite through an atmosphere.

As a matter of fact, the terms meteor and meteorite are used rather loosely, without the distinction set forth in the paragraph above. Whichever term is used, no great harm is done.

Just where one draws the line between a meteorite and an asteroid is a little hard, if not impossible, to determine. Many of the chunks of matter which fall upon the Earth are actually members of the asteroid belt. Perhaps you can make a rule of thumb and say that an asteroid is an asteroid until it hits Earth's atmosphere, at which time it becomes a meteorite.

While all travelers from space which come plunging down into the atmosphere are technically meteorites, the really tiny bits of junk that come out of space are called micrometeorites. This material actually is dust. The micrometeorites are so small that a microscope is needed to see them. Their path down through our atmosphere cannot be detected, for they are so tiny that they filter down between the molecules of the atmosphere, hitting so few molecules that there is little friction to raise their temperature. Most of the micrometeorites, while resembling dust, seem actually to be metallic dust. Most of them are tiny bits of iron.

But while the micrometeorites are able to filter down to the surface of the Earth, most of the small regular meteorites become so hot in their passage through the atmosphere that they vaporize and never reach the surface. Of the millions of meteorites entering Earth's atmosphere each day, only a rare few ever reach the surface.

Meteorites as a rule begin to heat up at the height of 60 miles above the surface of the Earth. While the atmosphere is extremely thin at such an altitude, the speed of the meteorite —close to forty miles a second (almost fifteen thousand miles an hour)—is so great that the small amount of friction is

enough to raise its temperature. The heat turns the surface material of the meteorite into a flaming gas. Unless the meteorite is a large one, all of its mass is turned into gas as it plunges deeper into Earth's envelope of air.

A meteorite large enough to leave an extremely long trail of light in the sky is called a fireball. One which explodes under the pressure and the heat of its passage through the air is called a bolide.

Meteorites, of course, are falling through the atmosphere all the time; but, except in unusual instances, we see them only at night when their flaming gases stand out against the dark.

Meteorites falling on the Moon would not show their customary streaks of light; for the Moon has no atmosphere to heat them up. On Mars, where the atmosphere is thin, they'd probably not begin to glow until they were much closer to the surface than 60 miles away. It is reasonable to suppose that many more meteorites reach the surface of Mars than of Earth because there is less atmosphere, and thus less chance of a meteorite's complete vaporization.

While it is impossible to say how many meteorites fall into our atmosphere, the estimate has been made that our average daily quota is seventy-five million meteorites large enough to make a streak of light in the night sky. If you included *all* the meteorites, the number (estimated, of course) would run to the order of forty-five billion. If you included the micrometeorites, the number would become utterly fantastic.

The total mass of the meteorites swept up by Earth each twenty-four hours has been estimated at from one thousand to ten thousand tons. The figures, as you can see, are not very definite. It's hard to be definite in a case like this. It is very likely that the fall of meteorites adds a million tons or more to the mass of Earth in a single year. This total would be

largely provided in the form of the gas of the burned-out meteorites, since the actual fall of solid material probably doesn't exceed an average of a ton a day. While this may seem a lot of added weight, it really is no more than a drop in a bucket. The Earth weighs six sextillion tons, which is six quadrillion (six followed by fifteen zeroes) times a million tons.

While there is a remote chance that some meteorites may be cosmic wanderers which have reached our solar system from galactic space (that is, from some part of our galaxy other than the solar system) by far the greatest number of them are members of the solar system. Even if they are not made up of material from the asteroid belt, they, like the asteroids, have well-established orbits, and obey the same laws of motion as anything else in the system.

Most of them probably are members of the asteroid belt. Others are simply some of the pieces left over after the solar system was built. Others may be associated with comets, which also are members of the solar system. At one time it was believed that the body of a comet might be made up of a cloud of meteorites. Recent research, however, has cast some doubt on this. It is probable, however, that cometary bodies may have some meteorites held together by gases frozen into ice. There is evidence that while the comets themselves may have very little meteoric material in their composition, they may travel in company with swarms of meteorites.

Meteorites are of two, possibly of three, kinds. For a long time it has been known that there are stony and metallic meteorites. Recent high atmosphere research by rockets indicate that there may be, as well, what might be called icy meteorites.

High altitude rockets sent up to explore the upper air have radioed back to Earth sounds picked up by microphones

included among their instruments. Over these microphones have come noises which sounded exactly as if they were caused by something pelting the rocket case—like meteorites hitting it. But when the cases were recovered, no marks were found upon the metal. If the rocket had collided with either iron or stony meteorites, there would have been some scratches or a dent or two. The fact that there were none has led to the theory that some meteorites may be hunks of ice.

Meteorites which reach the surface of the Earth can put on some rather spectacular fireworks, and we have records of thousands of such happenings. Through the years many such falls have been seen and reported; many of these reports reach far back into history.

The most spectacular fall of recent years occurred in Siberia on the night of June 30, 1908. The meteorite hit the Tungus forest, and the impact leveled trees for miles around. People were knocked from their feet 30 miles away from the center of the impact point. Windows 50 miles away were broken.

Recently, some doubt has been expressed as to whether this impact was made by a meteorite.

The site of the fall was not investigated by any scientist until 1927, nearly twenty years after the fall had taken place. Ten craters were found, the largest 160 feet across. But no crater large enough to have been caused by a meteorite such as would flatten square miles of trees was ever found. Nor was any meteoric material ever located.

There was another puzzling thing: On that night of June 30, the night sky had glowed brightly over a good part of the northern hemisphere. Sky glow was something that had not been previously observed in connection with a meteoric impact.

In 1960 a group of Russian scientific amateurs got up

an expedition to the site and came back with a report that was a piece of arrant foolery. The area, they said, still was doused with radiation. The Soviet press fell for this story and published articles suggesting that an atomic powered ship from outer space had fallen there.

Smarting under such a blatantly unscientific report, the Academy of Sciences in the U.S.S.R. sent our another expedition. No sign of radiation was found. The conclusion: The blast of 1908 was caused by neither a meteorite nor a spaceship, but by a comet.

The evidence, the official findings pointed out, indicated an explosion several hundred feet above the ground. This, the report said, is what could be expected of a body composed of dust and frozen gases—which is one way a comet could be constructed. The sky glow could have been caused by a scattering of cometary material in the upper atmosphere. The comet, the report estimated, probably was several miles in diameter and could have weighed close to a million tons.

The Russian report has not been subjected to evaluation by any other scientific body in the world.

The second great fall of the twentieth century also took place in Siberia. On February 12, 1947, during the daylight hours, something came smashing into the ground a couple of hundred miles north of Vladivostok. The impact hurled dust clouds 20 miles into the sky.

This time there could be no doubt that the impact was caused by a meteorite. Scientists, who rushed to the scene immediately, located 106 craters, some of them 100 feet across, and recovered five tons of meteoric material.

These are the only two big falls of recent years; but in the prehistoric past Earth was hit by meteorites of truly gigantic size. Many craters made by prehistoric meteorites have been wiped out by weathering; but a few still remain. Perhaps the best known is Meteor Crater, also known as

Canyon Diablo or Arizona Crater, near Winslow, Arizona. This crater, about four-fifths of a mile in diameter and nearly 600 feet deep, survived because it is located in dry country where there is little rain or weathering.

It is estimated that the meteorite which made the crater fell some 50,000 years ago, and that its mass probably was between 5,000 and 15,000 tons.

An even larger crater was discovered in 1950 by F. W. Chubb, a prospector, in the Ungava peninsula in the Province of Quebec in Canada. The crater is 2 miles across. In the bottom of it lies a lake 800 feet deep. The rim of the crater's walls rise 500 feet above the surface of the lake.

It is likely that if it were not for weathering, Earth would be as pockmarked with craters as is the Moon. Geologists suspect that many chains of lakes may be ancient craters dug by swarms of gigantic meteorites.

While most meteorites are lone travelers, others travel in large swarms. When such swarms plunge into Earth's atmosphere, they are called meteor showers. Some of these swarms are identified with the orbits of certain comets. The comets may still exist or they may have disappeared, but billions upon billions of meteorites apparently are following the orbits laid out for them by the comets.

While the association of the meteoric streams with a comet is not definitely proved, it is presumed that at one time the meteorites may have been part of the comet. But in some way, perhaps by the interference of planetary gravitation, these meteorites were torn loose from their comet. Now they continue to travel, if not the same old cometary orbit, at least an orbit very close to it.

When the Earth cuts into the orbit of one of the meteoric swarms, we have a meteor shower, with thousands of meteors visible to the human eye. In November, 1833, so many meteors streaked through the sky that 250,000 were

ticked off at one observatory between midnight and dawn.

So regularly does Earth cut through the orbits of the meteoric streams that meteor showers can be forecast precisely. They are given names, taken from the portion of the heavens in which they seem to originate. The Leonid shower seems to come from the direction of the constellation of Leo, the Perseid swarm from the constellation of Perseus, and so on. Actually, the swarms do not originate among the stars, but are members of the solar system. Calling them after the constellations is just a handy way to name them.

Stories concerning the discovery of craters and eyewitness accounts of meteoric falls would make enough thrilling reading to keep going on forever. We haven't the space here even to touch on most of these stories; but there is one story that we just can't pass up—the story about what may have been the largest meteorite ever to hit the Earth.

For years there has been a theory, fought over bitterly and now generally discarded, that the Pacific Ocean was created when a huge chunk of matter was torn from the Earth and hurled out in space to become our Moon.

In 1960, to replace this theory, Dr. E. R. Harrison, of the British atomic research establishment at Harwell, came up with another one.

The Pacific Ocean, he said, could have been created early in Earth's history by a giant meteorite—which may have been a chunk of matter from the asteroid belt. He calculated that the meteorite was approximately 120 miles in diameter, and punched a crater 100 miles deep and thousands of miles in diameter into the Earth's crust.

Such a blow would have unleashed terrific volcanic action, would have set the Earth to wobbling wildly; and the very crust itself would have crawled. When this reaction to the impact had worn itself out, the massive crater would have been partially filled, both by volcanic action and by the

shifting of the crust. The remaining dent would have been the type of shallow crater which is seen in many places on the Moon.

Another result, said Harrison, might have been that the old, primordial atmosphere of Earth was blown away and dispersed in space, either in large part or in its entirely.

Scientists are fairly well agreed that something happened to the atmosphere of primordial Earth—that we do not now have the kind of atmosphere which first formed around our planet.

Harrison's mathematics leave little doubt that such an impact as he theorizes would have created force enough for all the results he mentions. The force, he figures, would have been roughly equivalent to that produced if one atomic bomb of 20 kilotons (20,000 tons of TNT) were exploded over every square yard of area involved.

The rugged country which rims the Pacific, he says, very well could be the weather-worn rim of debris splashed out of the crater by the impact.

Another point he makes is that the Pacific, in general, is not underlain by the normal light crustal rocks, such as granite, which are found elsewhere on Earth. The explosion which created the crater, he believes, could have dispersed these crustal rocks.

And observing that, in general, all oceans and seas are underlain by denser rock than that found in the continental crust, he poses the question of whether all of Earth's ocean basins might not have been carved out by impacts of matter plunging down from space.

14.

Jupiter and Saturn: Into Strange Country

SO FAR WE'VE BEEN ON FAMILIAR GROUND.

The planets we have discussed are formed of rock and metal. Their sizes are reasonable. They are all the kind of planet that a man could walk on. Conditions on them may be rather trying, perhaps even deadly; but with the kind of deadliness that one can understand.

But now, out beyond Mars and the asteroid belt, we come to unfamiliar planets. We step into a strange country indeed. Here are four planets—Jupiter, Saturn, Uranus and Neptune—to which man will never go. To some of their moons, perhaps; but not to the planets themselves.

There are two good reasons why we'll never try to land on any of these four planets. The first and most important is that if we landed, we'd never get away. The escape velocity on each of them is so great that no power we can think of at

the moment would give us the lift necessary to get a spaceship away once we had landed there. The escape velocity on Earth is 7 miles a second. On Jupiter it is 37 miles a second; on Saturn, 22; on Uranus, 13; and on Neptune, 14.

The second reason is that there may be nothing on these planets on which a ship might land. Somewhere within the interior of each of them, of course, a spaceship would finally come to a stop; but you could scarcely call it a landing. More than likely, before a ship stopped it would have been crushed by the tremendous atmospheric pressure.

For these giant planets, the smallest of which, Neptune, is sixty times larger than the Earth, are not planets as we think of planets. They are, rather, hideous experimental test tubes in cold chemistry. For all of them are cold.

But each of these planets does have moons. Some of the moons are larger than our Moon; a few of them are not a great deal smaller than Mars. It is entirely likely that some day we'll land on some of them. What we'll find there no man yet can say.

The best evidence is that most of the moons are cold and airless. There is one exception: Titan, Saturn's largest moon, does have an atmosphere.

The moons, even if they served no other purpose, would make excellent observatory stations from which we could study the baffling planets about which they revolve.

Baffling is the word, precisely.

As in the case of Venus, we cannot actually study these planets themselves. All that we can see of them are the vast cloud covers which conceal them—if "cloud" is the word.

There is a suspicion that in each of these planets matter as we know it has gone "over the hill" into a state which may be wholly unknown to us, or which, at best, is known only as a matter of theoretical speculation.

Aside from the Sun, Jupiter is the biggest object in the

solar system. Its diameter is 88,770 miles, eleven times the diameter of the Earth. Thirteen hundred Earths would fit rather neatly into the volume of space occupied by Jupiter. But Jupiter's mass is only 318 times greater than the mass of Earth. Jupiter's density figures out to 1.3 times that of water, while Earth's is 5.5 times that of water.

With such a low density, Jupiter cannot possibly be constructed of the same material as Earth. At one time it was believed that Jupiter and the other giant planets might have solid metallic cores; but now this is questioned. At times the giant planets are called the gas planets; and this may be the answer. They may, in sober fact, be constructed of nothing but gases.

Jupiter's average distance from the Sun is 483.9 million miles, making it more than five times farther out than Earth. It can be as close as 367 million miles from Earth or it may be as much as 600 millions miles away. Its orbit about the Sun takes almost twelve years—11.86, to be exact.

Like the Earth, Jupiter is squashed in at the poles. Its diameter at the equator is 88,770 miles; through the poles, it is only 83,010 miles. This variation is accounted for by the planet's rapid spin around its own axis. Jupiter's day is five minutes less than ten hours long. This means that the speed of rotation at the equator is in the neighborhood of 28,000 miles an hour. The centrifugal force set up by this rapid spin causes the pronounced equatorial bulging.

But while we can smugly say that Jupiter has a certain rate of rotation, that is not entirely accurate. For all parts of Jupiter do not spin at the same rate. The rotation is fastest at the equator, with other areas of the planet rotating at slower rates. This variation in rotation would be possible only in a gas planet; it is very similar to what happens on the Sun. But one can predict the rotational rate of various latitudes on the Sun, for there the differences in the rates of rotation are con-

stant. On Jupiter there is no constancy. Certain areas speed up and others slow down, apparently for no reason. And what is worse, the rotational rate is different in the opposite hemispheres. A study of the markings on Jupiter show that there can be a difference in the rate of rotation of as much as twelve minutes.

At one time it was believed that Jupiter's upper regions, the regions that we see, were composed almost entirely of ammonia and methane. Ammonia is the gas that, mixed with water, is the foul-smelling, eye-watering cleaning agent you buy in the grocery store. Methane is a deadly gas which, on Earth, can make mines a dangerous place to work.

Now, however, it appears that Jupiter's topmost layers are composed largely of hydrogen and helium, with methane and ammonia present as little more than impurities.

Some years ago it was believed that Jupiter was a hot body, a sort of junior-size Sun—not hot enough to shine, but warm enough to glow. Now we know the planet is cold. The surface temperature is 150° below zero, Fahrenheit. This temperature fairly well rules out the presence of ammonia as a gas. Ammonia freezes at 144° below zero, so most of the ammonia in Jupiter's atmosphere would be solid. There would be a little ammonia vapor, enough to be detected by the spectrograph. Methane, which has a lower freezing point—it turns into a liquid at 190° below zero and freezes at 230° below—could be present as a gas without any trouble. Hydrogen holds out until 436° below zero before it becomes a solid. Water, of course, would not exist in its liquid form. Water on Jupiter, if any exists, would be in the form of ice.

It is not likely there would be any free carbon or nitrogen in the atmosphere. Methane is composed of carbon and hydrogen; ammonia is a combination of nitrogen and hydrogen. So any carbon or nitrogen present probably would be in combination with hydrogen, forming ammonia or methane.

Jupiter, seen through the telescope, ordinarily is the most colorful of the planets. There are times, however, when all the color fades and it is about as drab a thing as you could run across.

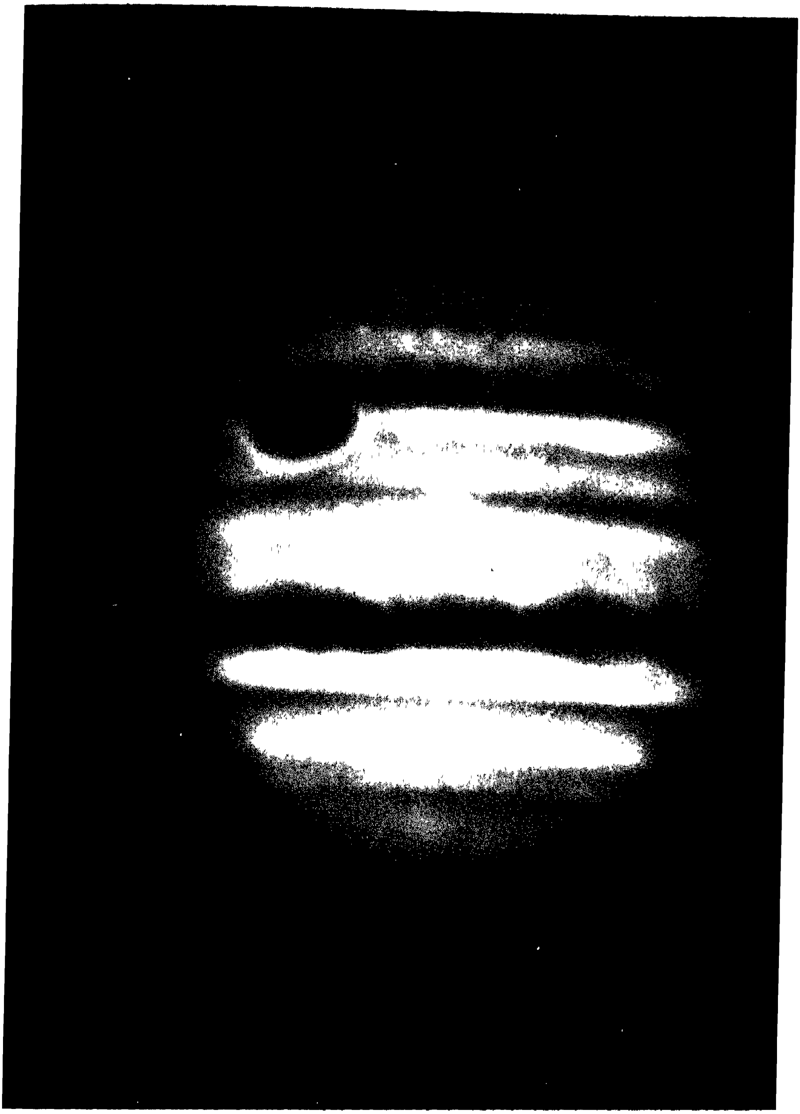
It is speckled and banded. Fairly regular belts of varying color have been charted, parallel to the equator. The colors change through most of the colors of the spectrum. At times some of the belts even are green, a most unusual color for a cloud formation. The belts themselves do not seem to be flat or uniform, but seem to be a combination of various cloud structures.

Jupiter has a lot of spots, but the Great Red Spot has become, through the years, one of its most prominent features. The Red Spot, and in fact all of Jupiter's features, fades or become brilliant intermittantly. There seems to be no consistent period in which this happens. The charges come about at random, with no apparent cause.

The Great Red Spot has been known for almost 300 years and seems to be at least a semi-permanent feature, although it floats about on the surface of the planet, ranging about 20,000 miles east or west from its average position. Its size and shape have remained about the same since the time when it was discovered—it is 30,000 miles long by 7,000 miles wide. It thus covers an area approximately as large as the entire surface of the Earth.

Just why it was called the Red Spot no one knows. It can be seen in many colors—pink, mauve, rose: almost anything but red.

No one knows, of course, what makes up the Red Spot. The best guess seems to be that it may be made of ice. But not ice as we know it. Rather a highly compressed ice, variously known as Ice-V, Ice-VI, Ice-VIII, and so on. Nothing, you can bet, as simple as that cube you take out of your refrigerator. Another theory is that the spot may be the



Jupiter photographed in blue light. The Great Red Spot is on the upper left hand face of the planet and the belts are shown. (Mount Wilson and Palomar Observatories)

result of volcanic action. But, once again, probably not volcanic action as we know it on the Earth. If there is volcanic action on Jupiter, it probably takes the form of a huge bubble rising from the interior of the planet. Reaching the surface, such a bubble would burst and eject vapors into the thinner clouds of the upper atmosphere.

While most speculations about Jupiter, of course, have centered on the Red Spot, scientists are equally as puzzled to account for the presence of, or the changing colors in, the other features on Jupiter. Perhaps some day, when we land on one of Jupiter's moons and train our instruments on the planet from a distance of only a few thousand miles instead of many million, we will get some of the answers.

Not only the answers to the puzzles of the color and the features, but the answers to many other puzzles. For some years now radio telescopes have been picking up strong signals from Jupiter. These radio waves represent an energy which is equal to the explosive power of 100 million tons of TNT per second. Scientists have determined that five specific areas on Jupiter do most of the broadcasting. This seems to knock out the old theory, which held that the signals originated with gigantic electrical storms raging just beneath the cloud surface. Electrical storms would be unlikely to confine themselves to five specific spots upon the planet. The signals have what seem to be a pattern, producing bursts equal to the power of ten H-bombs at the approximate rate of one each second. The bursts don't erupt as units, but emit separate sprays of radio noise.

As with most of the other planets, we have a good deal of data on Jupiter. As in the case of the other planets, we have trouble explaining the data.

We do believe, however, that we know something about the structure of Jupiter, knowledge based upon our information about its gravity, density and mass.

Dr. W. H. Ramsey, of Manchester, England, has proposed a model which, at the moment, seems the best theoretical explanation of what Jupiter really is.

The basis of this model is that the planet's core has an infinite density. That is, that the atomic structure of it is so tightly packed, so jammed together, that there is no more room at all, that it cannot become any smaller or any heavier.

This was the condition of the great glob of matter which theoretically provided the material for the creation of the universe; but with this distinction: On Jupiter we are still dealing with atoms, while in the "big-bang" situation we are dealing with radiation. Close to the same situation exists in the Sun, except that in the Sun we are dealing with sub-atomic particles—with atoms broken down into their component parts.

Ramsey's theory says that the weight of the atmosphere compresses each successive layer of the atmosphere, changing its form. First we have the gaseous atmosphere at the surface. But at some distance beneath the surface the gas changes to a material of a soupy consistency. This then becomes matter with a slushy consistency; and from slush it turns into solid hydrogen.

But as the pressure continues to build up with depth, the solid hydrogen, at 5,000 miles or so beneath the surface, suddenly changes into metallic hydrogen.

This would happen when the pressure was equal to 800,000 Earth atmospheres. The reasoning is that solid hydrogen has certain limits to its compressibility. That is, it reaches a point at which it can be squeezed together no tighter. When the weight of the atmosphere above it builds up beyond this point, something has to give.

By being forced to change from a solid to a metallic state, the hydrogen gains a new extension of compressibility—that is, it then can be squeezed together even tighter.

You understand, of course, that hydrogen has never been changed to a metallic form in any laboratory on Earth. But the mathematics of physics predicts that it can be done.

At a depth of 37,400 miles from the surface, the pressure inside Jupiter has reached the equivalent of 93 million Earth atmospheres. If you want to imagine how great a pressure that would be, envision as many atmospheres as the Earth is miles from the Sun.

With this kind of pressure, infinite density has been reached and we have in the center of the planet a core, pushed together beyond all further compressibility, 45,000 miles across (six times as great as the diameter of the Earth).

While there may be slight differences among them, because of varying pressure and density, this same model also can be applied to the other three giant planets, Saturn, Uranus, and Neptune.

There is one more thing about Jupiter that we must talk about before we go on to the other outer planets—and that is, the moons of Jupiter. With twelve of them in its possession, Jupiter is a sort of miniature solar system all by itself.

The innermost moon is generally called Jupiter V, or at times simply V. An attempt has been made to name it Amalthea, but the name does not seem to have caught on.

While the distance from Jupiter ordinarily given for V is 112,000 miles, the moon is actually only about 70,000 miles above the surface of the big planet's atmosphere. The reading of 112,000 miles measures from Jupiter's center.

Jupiter V is only about 150 miles in diameter. It revolves about Jupiter once every twelve hours, which makes it just about the most lively moon in the solar system. Indications are that it is losing its fight against the tremendous gravity of the big planet and is tightening up its orbit, year by year inching in closer to the planetary atmosphere which is waiting to engulf it. But this is a slow process. Jupiter V still has some-

thing like seventy or eighty million years before it is gulped down by Jupiter.

Jupiter V is called V because it was the fifth moon of Jupiter to be discovered. Four others—Io, at 262,000 miles from the planet; Europa, at 417,000 miles; Ganymede, at 666,-000; and Callisto, at 1,170,000—all were discovered by Galileo, the first modern astronomer, in 1610. Jupiter V was discovered in 1892.

Io is slightly larger than our Moon, but seems to be somewhat more dense. It is probably a metallic world rather than a stony world such as the Moon is believed to be. Seen in the telescope, however, Io is brighter than could be expected if it were metallic. The answer seems to be that its surface is covered by something which reflects light well. Although it is too small for detail to show up well, definite markings can be distinguished on its surface, and a brighter belt exists around its equator.

Europa, the third satellite, has a diameter of 1,950 miles and, like Io, has a greater density than does our Moon. Despite the fact that sunlight, by the time it gets to Jupiter, is becoming rather faint, Europa practically glitters. Astronomers estimate that it reflects about 75 percent of all the sunlight it catches, which is an unusually high reflective index. More than likely its surface is covered with some sort of matter (no one even has a good guess as to what it might be) that sparkles and glitters like artificial snow on a Christmas tree.

Ganymede is the second largest of the Jovian satellites. At 3,200 miles in diameter, it is only 1,000 miles in diameter smaller than Mars. But despite its size, it has no more mass than our Moon (that is, it weighs no more than our Moon). It has markings which remind one of the markings on Mars. But there can be no speculation about these markings being vegetation, as their counterparts on Mars may be. None of the moons of Jupiter is warm enough to support any kind of

life. While all four of the larger moons are big enough to maintain some sort of atmosphere, no trace of one has ever been found. If any of them has an atmosphere, it is thin indeed. The likelihood is that they have none. In that case, they must be bitterly cold—almost as cold as surrounding space.

Callisto, which has a diameter just 20 miles bigger than that of Ganymede, is the real puzzle of the lot. It has only half the mass of our Moon, and a density only just a little greater than the density of water. Its escape velocity is something less than a mile a second. Surface features have been seen, but they are vague and often hard to make out. Callisto is not nearly as bright as any of the other, larger, moons.

A guess has been made that Callisto is made up of ice and some light rock (more than likely pumice) loosely stuck together. But no one really knows.

The seven other satellites of Jupiter fall into two groups. Satellites VI, VII, and X (they have no names) are located some seven million miles from Jupiter—VI at 7,120,000 miles, VII at 7,290,000 miles, and X at 7,300,000 miles. They are numbered in the order of their discovery. Of the three, VI is the largest, with a diameter of 100 miles. The diameter of VII is 35 miles, and that of X, 15 miles.

The members of the second group, located somewhere in the neighborhood of 14 million miles from Jupiter, are renegades. They circle the planet in the wrong direction, moving clockwise. It is believed that they are not actually moons, but asteroids which ventured too close to Jupiter's gravitational field and were trapped.

The four renegades are no great shakes when it comes to size. VIII, the biggest, is 35 miles in diameter; XII is 14; XI is 18; and IX is 17. XII, the last to be discovered, was spotted in 1951. Jupiter may have other moons, and, if so, they will be found in time. After all, it is no easy task to spot

a dot less than 20 miles across at our distance from Jupiter.

From any of the inner satellites, Jupiter would be a breathtaking sight. It would fill a large part of the sky, and its colors and surface features would be far more pronounced than they appear through a telescope on Earth.

Apparently all of Jupiter's moons, like our own, present the same face to the planet, the periods of their revolution on their axes being the same as those of their revolution about the planet.

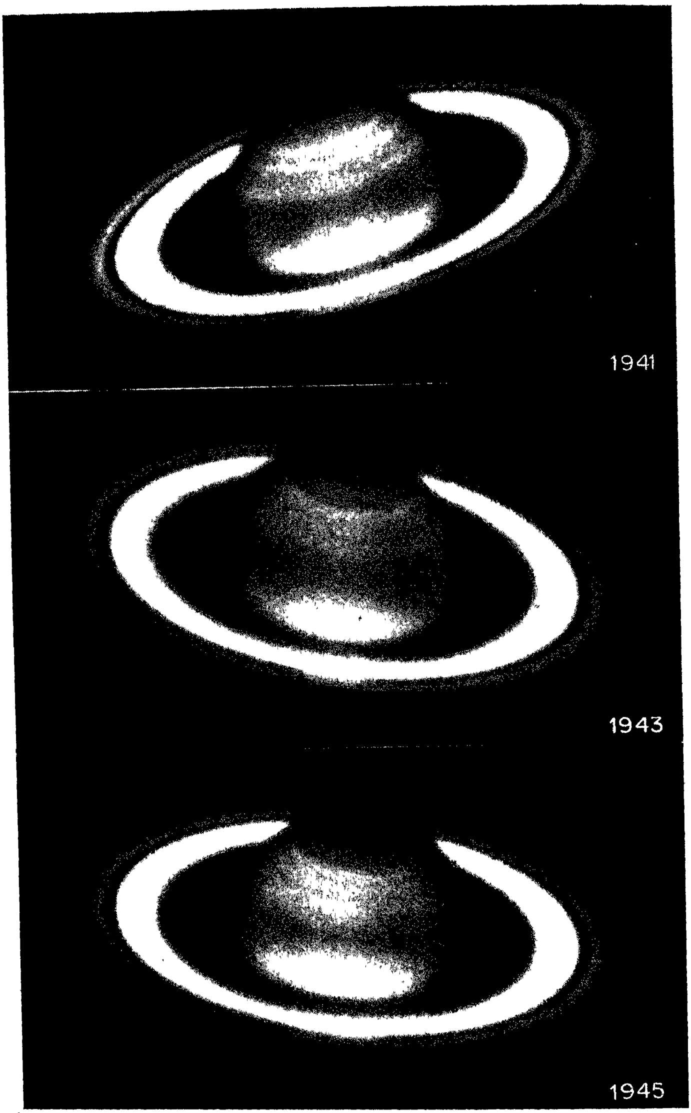
While Jupiter is the most colorful thing in the solar system, there is no doubt that Saturn, with its rings, is the most spectacular.

Saturn is very much the same kind of planet as Jupiter, even to the bands and occasional spots. These, however, are not as pronounced, nor as colorful as are Jupiter's.

Saturn is 886.1 million miles from the Sun and requires 29.5 of our years to complete its orbit around the Sun. Its day is ten hours and fourteen minutes long. Its diameter is 75,100 miles; but, like Jupiter, it has an equatorial bulge, with the diameter from pole to pole some 8,000 miles less than the diameter through the equator. While Saturn is 763 times bigger than the Earth, it has only 95 times Earth's mass. The temperature at the top of its atmosphere is 283° degrees below zero, Fahrenheit. The escape velocity is 22 miles a second, but its gravity at the surface is only slightly more than that of Earth. If you weighed 100 pounds on Earth, you'd weigh 115 pounds on Saturn. Radio waves similar to those detected as coming from Jupiter also have been received from Saturn.

But when one thinks of Saturn, he thinks first of the rings. The rings are so thin that when they are edge-on to us they can be barely seen. But when the planet is tipped, they can be seen clearly. They extend out from the equatorial plane and measure some 170,000 miles across.

There are three main rings. The outermost one, known



Photographs of Saturn, taken at different times, show how the tilt of the rings change. There are also times when we are looking at the rings straight-on that they appear to be no more than a narrow white band extending across the planet's equator. (Lowell Observatory photos)

as Ring A, measures 10,000 miles across. Between Ring A and Ring B is a plainly marked gap of 1,700 miles. Ring B is 16,000 miles wide and is much brighter than the outer ring. Inside Ring B is the Crepe Ring, 10,000 miles wide; and between it and the planet is a clear space of 9,000 miles. The Crepe Ring is not as bright as the two outer rings, and is sometimes hard to see because it is so transparent that the face of Saturn can be seen through it. In addition to the gap between Ring A and Ring B, called the Cassini Division, there are other smaller gaps which can be seen only with a powerful telescope.

The thickness of the rings is estimated at 10 miles, or perhaps slightly more—which explains why they are hard to see edge-on.

Strangely enough, though time after time we have been forced to say that we could not understand or explain certain planetary features, we *are* able to explain the rings.

At one time it was believed the rings were the debris of a moon which had broken up. But now we're fairly certain that here we have a situation similar to that in the asteroid belt. It is likely that the rings are formed of matter which was intended as a moon, but which was never able to form because of Saturn's tidal force. The moon which tried to form was just too close to Saturn; it never had a chance. The brightness of the rings, it is believed, is due to a coating of ice which has formed over the material which makes up the rings. This material, incidentally, probably ranges in size from bits as small as pebbles to boulder-sized chunks. And while the material of the asteroid belt is widely scattered, the rings of Saturn are tightly held together by the mighty forces exerted by the planet.

Saturn has only a slightly smaller number of moons than Jupiter—nine confirmed and one suspected.

Titan, Saturn's largest moon and the largest in the solar

system, is about 3,500 miles in diameter. This makes it bigger than Mercury, but not as big as Mars. If it were not a moon by virtue of the fact that it circles a planet, it would be large enough to be a planet in its own right.

Titan, of all the moons we know, is the only one that has an honest atmosphere. But before you go grasping at hope: The atmosphere appears to be composed largely of methane, which immediately rules out any possibility of life as we know it.

The escape velocity of Titan is slightly over 2 miles a second, which explains why the moon has been able to hang on to an atmosphere.

Titan is at such a great distance from Earth that its surface features are hard to make out; but two large dusky patches south of the equator have been pinpointed. Enough detail cannot be seen to allow even the wildest guess as to what these patches may be.

Titan is 760,000 miles out from Saturn and, like all of Saturn's other moons, keeps one face eternally turned toward the planet, exactly as does Earth's Moon.

To the planet side of Titan, between its orbit and Saturn's rings, are five other moons. Their names, counting outward from Saturn, are Mimas (300 miles in diameter and 113,000 miles out from Saturn), Enceladus (400 miles in diameter and 149,000 miles out) Tethys (800 and 183,000), Dione (1,000 and 235,000), and Rhea (1,100 and 328,000). All of them, except Dione, appear to have little mass in relation to their size. It is likely they are composed of ice and pumice, perhaps packed together rather loosely. Dione seems to be much heavier.

You may have noticed that these six inner moons get progressively larger as you move away from Saturn. But when we come to Hyperion, the seventh moon, the first one to the space side of Titan, the progression in size breaks down.

Hyperion is only 200 miles in diameter. It lies at a distance of 920,000 miles from Saturn.

Iapetus, the eighth moon, is a large one again—probably about 2,000 miles in diameter. Astronomers have had a tough time determining the size of Iapetus. At one time it was tagged at about 1,000 miles across; but now it is agreed that this figure was far too low and that 2,000 miles is nearer the mark. It is just barely possible that Iapetus has a very thin atmosphere; but we don't know for certain. Iapetus is 2.2 million miles from Saturn.

There is something most peculiar about this far-out moon: It varies in brightness, and the variation takes the form of a regular pattern. When it lies west of Saturn, it is very brilliant; but when it moves around to the east of the planet—it takes about five weeks for the satellite to move from farthest west to farthest east—it grows dim. Iapetus is too small and too far away to allow us to discover the reason for this. One theory is that the moon may, at one time, have been in a collision with some other body in space. The collision could have sheered off a part of the satellite's surface to form a flat area which acts as a mirror. When this mirror is turned toward us, it reflects most of the light that falls upon it. When it is turned away, the normal surface reflects considerably less light, and the moon is dimmed. Another theory is that Iapetus does have an atmosphere, and that when it moves back of Saturn and away from the little warmth which the Sun affords at that distance, the atmosphere freezes and falls to the surface as ice. It is the Sun gleaming on the ice which makes the moon seem bright. As it moves across to the sunward side of Saturn, the ice melts, Iapetus has an atmosphere again, and it shines less brightly. But here again is something about which, on the basis of our present data, we can only theorize.

The ninth, and outermost, of Saturn's moons is Phoebe.

Phoebe, like the outer moons of Jupiter, is a renegade. It travels in a clockwise motion, in a direction opposite to that of the other moons. Its 150-mile diameter makes it a tiny mote at the enormous distance of 8.05 million miles from Saturn. So far does it have to travel in its orbit that it takes a year and a half of our time for it to complete one revolution about the planet.

Back in 1903, W. H. Pickering, at that time one of the leading American astronomers, announced the existence of a tenth moon of Saturn. He worked out its orbit and named it Themis. But from that day to this it has not been seen again. Astronomers now believe that what Pickering saw was not a moon. There is no doubt that he saw something, which must have acted very much like a moon of Saturn. What it was, perhaps no one will ever know.

15.

Uranus and Neptune: New Neighbors

THE PLANETS WHICH WE HAVE WRITTEN ABOUT SO far are bodies which have been known from ancient days. There was no missing them. They were there, shining in the sky for everyone to see. Long ago—long before history dawned—man had figured out that they were different from the stars. For a long time men believed there were only five planets: Mercury, Venus, Mars, Jupiter and Saturn. But finally they realized that there were six—that Earth was a planet, too. But that was the end of it. There were no other planets.

But in 1781, William Herschel discovered Uranus. And because the orbit of Uranus didn't behave the way it should, astronomers guessed that there might be another planet even further out, which was hauling Uranus' orbit out of true. So they went looking for it. In 1846 it was discovered jointly

by John Couch Adams and Urbain Joseph Leverrier, and it was called Neptune.

But there still was something wrong. The discovery of Neptune still didn't explain some of the peculiarities in the orbit of Uranus. So once again astronomers went hunting for another planet, Planet X (the X standing for unknown), still farther out than Neptune. In the spring of 1930 Planet X was discovered by Clyde Tombaugh, a young astronomer at Lowell Observatory at Flagstaff, Arizona. Planet X became known as Pluto.

So now, instead of five, instead of six, the planets numbered nine; and the diameter of the solar system was increased to a bit more than four times what it once had been.

And is this the end? We rather think it is. But don't be too surprised if one of these days some astronomer comes up with another planet, the tenth, far beyond Pluto's orbit. To be sure, it's not too likely to happen; but it could. Past experience has shown us, without question, that you can't arbitrarily place a period at the end of the solar system.

There have been those who described Herschel's discovery as an accident, but that is hardly fair. True, Uranus, which can be detected with the naked eye as a very dim body, if you know just where to look for it, had been seen many times before by many people who thought it was a star. Herschel himself did not recognize it as a planet when he first chanced upon it. He thought it was a comet. But after further study, he found that it was a planet. John Flamstead, a British astronomer, back in 1690, had included it in a star map as just another star. Flamstead recorded seeing it on six occasions between 1690 and 1716, but he always reported it as a star.

The point is that Herschel, who was engaged in a systematic charting of the entire sky at the time he ran across

Uranus, was the first to recognize this dim point of light as actually being a planet.

Uranus and Neptune are both giant gas planets, in the same class as Jupiter and Saturn. Their composition is virtually the same, their structure the same. The only things about them which differ are their bare statistics.

Uranus is 1,783,000,000 miles from the Sun, the first of the planets to break the billion-mile mark. Uranus, in fact, is closer to two billion miles distant from the Sun than it is to a billion. It requires eighty-four of our years to make one circuit about the Sun. Since Herschel's discovery of the planet, only two Uranian years have passed. The great distance it has to cover does not entirely account for Uranus' long year. The planet also moves slowly, plodding along at a mere 4 miles a second as compared to Earth's orbital speed of 18.5 miles per second. The farther out from the center of the system you go, the slower the orbital speed. Neptune moves at 3.4 miles a second, and Pluto at even 3.

Like the other giant planets, Uranus has a rapid rotation on its own axis, making a complete turn every ten hours and forty-five minutes. Like the other gas planets, it is flattened at the poles, with an equatorial bulge. At the equator it is 32,000 miles in diameter. It is denser than Saturn, but its density is small as compared to Earth's. You could tuck sixty-five Earths inside Uranus; but it has the mass of only fifteen Earths. The temperature at the surface is 310° below zero, Fahrenheit. Uranus shows belts, as do Jupiter and Saturn.

The one peculiarity of Uranus which sets it apart from the other planets is that it rolls along its orbit, with one of its poles almost pointing at the Sun.

Large telescopes show Uranus as greenish in color, with a white equatorial belt and some other, fainter belts. Small spots occasionally are seen. But we know very few details about Uranus.

Uranus has five moons and these orbit in the equatorial plane, which means that we can see them making complete turns around the planet. Uranus, by insisting on lying on its "side" (compared to the rest of the planets) exposes them to our view.

Counting outward from Uranus, the moons are: Miranda, 200 miles in diameter and 76,000 miles from Uranus; Ariel, probably 1,500 miles in diameter and 119,000 miles out; Umbriel, probably 800 miles in diameter and 166,000 miles out; Titania, probably 1,500 miles in diameter and 272,000 miles from Uranus; and Oberon, probably 1,500 miles in diameter and 364,000 miles from the planet. For a long time it was believed that Uranus had only four moons; but Miranda was discovered in 1948 by Gerald P. Kuiper. At the time Herschel discovered the planet, he announced it had six moons. Four of them turned out to be stars. Later, in 1851, Ariel and Umbriel were discovered to boost the then total to four.

There is, as you may have gathered from the figures, a good deal of uncertainty about the size of the moons. None of them is big enough, however, to have an atmosphere.

As we have said, it is just barely possible to see Uranus with the naked eye. Neptune you cannot see without a telescope. Its equatorial diameter is 26,800 miles, smaller than that of Uranus; and it is 2,793,000,000 miles from the Sun. Light from the Sun requires more than four hours to reach Neptune's surface. Almost 165 of our years are used by Neptune in making its orbit of the Sun. It spins on its axis once every sixteen hours. Its temperature is 360° below zero, Fahrenheit. Apparently it also has belts, like the other giant planets; but it's so far away they are hard to observe. It is the densest of the four giant planets, but it's still not nearly as dense as Earth.

Neptune, as was mentioned above, was discovered as a result of Uranus' failing to show the sort of orbit it should

have displayed. From 1716 to 1822 Uranus moved too rapidly. It then reversed itself and moved far too slowly—no way for any proper planet to behave.

It was clear from this that some unknown force was acting upon Uranus. It must be understood that, while each planet is on its own and follows its own path around the Sun, it is not immune to the gravitational influence of other bodies out in space. There is a considerable amount of tugging and hauling going on, the forces of the planets acting upon one another. Mars is influenced in its course by the pull of Earth and Jupiter. Earth's orbit is influenced by the pull of Mars, Jupiter and Venus. There is no planet which does not feel—to some degree, however slight—the influence of the gravitational forces of the other planets.

But even when all the factors involving the attraction of the other planets were calculated, Uranus still was not acting in the way it should.

There was only one answer: There was an unknown body somewhere which was affecting the Uranian orbit. So the search was started.

In 1843 John Couch Adams began, in Britain, a detailed study of the movements of Uranus. As a result of this study, he was able to determine the hypothetical location of the unknown planet.

He sent his calculations to George Airy, the Astronomer Royal of that day. But Airy, busy with other matters—and perhaps without too much faith in Adams—did nothing about it.

In 1846 Urbain Leverrier, a French mathematician, published a paper which revealed that he had made the same study as Adams, and had obtained the same results. Apparently, at the time he published the paper, he had not heard of Adams' work.

But before Airy—reminded of Adams' work by Lever-

rier's paper—could accomplish anything, two astronomers working at the Berlin Observatory, Johann Galle and Heinrich d'Arrest, working with Leverrier's calculations, found the planet.

One of those undignified squabbles which occasionally arise in scientific circles arose between the supporters of Adams and the friends of Leverrier. Adams, his friends pointed out, was the first to have worked out the position of the new planet. But, contended the friends of Leverrier, it was by the means of the Frenchman's work that the planet had actually been discovered.

It ended, finally, with the two men being given joint honors for the discovery of the planet, which was named Neptune.

At the time of the discovery of Uranus, that planet and Neptune were close to one another. In 1822 they were in a straight line with the sun. Before 1822 Neptune had tended to drag Uranus forward on its orbit, hurrying it along; after 1822, with Uranus passing Neptune because of Uranus' smaller orbit, Neptune had applied the brakes and tried to slow down its neighbor. If Uranus had been discovered when it was on the opposite side of the Sun from Neptune, little discrepancy would have been noted in its orbit and the discovery of Neptune might have been delayed for many years.

Neptune has only two moons, but each of them is fairly interesting. The first, Triton, discovered shortly after the discovery of Neptune itself, is 220,000 miles from the planet and has a diameter of 3,300 miles. While not the largest, it is the most massive moon in the solar system. No accurate measurement has been made, but there is a good possibility that Triton may be as massive as Mercury. This must mean that its escape velocity is fairly high; and there is a good possibility, therefore, that it has an atmosphere. It completes

an orbit about Neptune every six days (our days), and moves in a retrograde (clockwise) direction.

The second moon was discovered in 1949 by Kuiper, and is named Nereid. It is only about 200 miles in diameter and has a strange, lop-sided orbit. At its closest, it is a million miles from Neptune; at its farthest out, 6 million. It requires almost one of our years to complete its orbit and it, too, moves in a retrograde direction.

There is just a possibility that Nereid may be a comet. Its elongated orbit and the comparatively long period needed to complete its orbit seem more suitable to a comet than to a moon.

16.

Pluto: The Last Outpost

OUT ON PLUTO, 3,666,000,000 MILES FROM THE Sun, we are at the edge of the known planetary system.

Pluto is the most recently discovered, and in many ways the most baffling, of all the planets. Baffling, of course, because it is so far away and so hard to observe in detail.

Pluto is an extremely sloppy planet. While we give the figure of 3,666,000,000 miles as its mean distance from the Sun, the actual distance varies greatly. At times, during its closest approach to the Sun, Pluto is only 2,766,000,000 miles out, closer than Neptune by some 25 million miles. At its farthest out, it is 4,567,000,000 miles distant from the Sun.

At the moment, Pluto is nearing the point at which it is closest to the Sun. From 1969 until 2009, it actually will be closer to the Sun than is Neptune. It will be as close

to the Sun as it can ever get in the year 1989. By 2113 it will have reached its farthest point—over 4.5 billion miles away from the Sun. For years on either side of that date it will be so far from us that it will be observable by only the biggest telescope.

Another peculiarity of Pluto's orbit is that it is tipped out of line from the orbits of the other planets by 17 degrees. If it were not for this tipping, there would be a far-out possibility that on some distant day it might collide with Neptune as it crossed that planet's path to move in closer to the Sun. But the tip of Pluto's orbit gives the two planets a third dimension of movement, instead of the two dimensions they would have if their orbits were in the same plane. And this extra dimension almost entirely eliminates any possibility that they will ever crash.

Pluto requires 248 years to make an orbit of the Sun. Its apparent diameter is 3,600 miles, which makes it just slightly larger than Mercury. And when you have said that of Pluto, you have said about everything we know.

The discovery of Pluto stemmed from the same circumstance as that which brought about the discovery of Neptune. The orbit of Uranus would not behave; so another planet was sought to explain its misbehavior. When Neptune was found, everything apparently was all right again. But about half a century later, Uranus began to waver once more—not very much, but enough to disturb the astronomers.

Was it possible, they asked, that there was yet another planet?

No one could say. It was just possible that the waver was due to error in observation. But one man, Percival Lowell, thought otherwise. He started the hunt for another Planet X.

The discoveries of Uranus and Neptune had been made by the use of the naked eye and the telescope. Now man had

another tool: photography. By taking a telescopic picture of one section of the sky, and then taking another picture of the same section a few days later, the pictures of that section as it appeared on two different nights could be compared. The points of light which had remained in place would be stars or distant galaxies. Anything that had moved would be a member of the solar system. For while the stars do move over long periods of time, they are so far away that no movement can be noticed over the space of many years, let alone in the space of a few days.

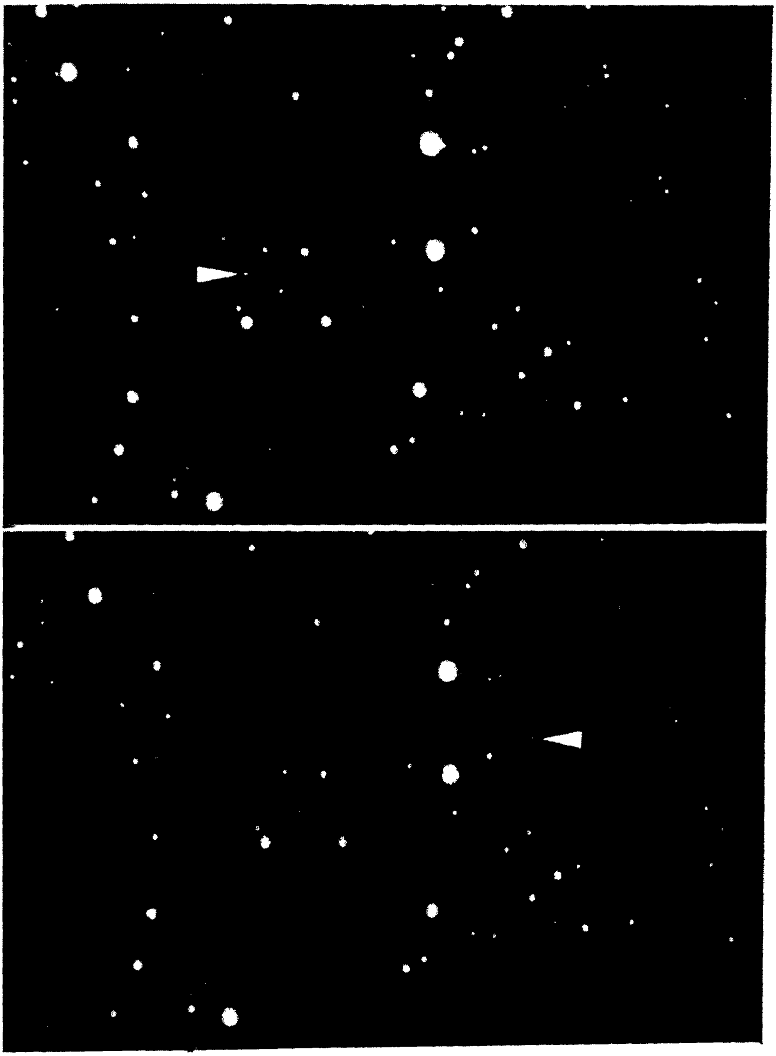
Operating from Lowell Observatory, which he founded at Flagstaff, Arizona, Lowell began his search for the trans-Neptunian planet in 1905. For two years the search was carried on, with no results.

At that time photography was a fairly crude affair. The emulsions were less sensitive to light than they are today, and less reliable. Nor did the type of sky camera we have today exist.

There was another reason for the failure. In 1905 Pluto was much farther away than it is today, and many degrees from the planetary plane, along which the search was made. At that time no one guessed that the unknown planet's orbit might be tipped above or below the plane in which the other planets moved. So, naturally, the search was concentrated in a straight line out from the other planets.

Too, at that time photographic plates were examined and compared with the aid of a hand magnifying glass—a slow and weary process. Later, a blink microscope was used. The blink microscope makes a moving object appear to jump as the two plates are compared.

From 1914 to 1916 the search was resumed again. Once again there were no results. But later, after Pluto had been discovered, a re-examination of the plates taken in the 1914-16 period showed that weak images of the planet had been caught, but not recognized.



These are the Pluto discovery plates. The top picture, taken on January 23, 1930, shows Pluto (pointer) far to the left of the two bright stars in the center of the plate. The second picture, taken on January 29, six days later, shows Pluto to the right of the two bright stars. The fact that Pluto had moved in six days' time meant that it could not be a star. (Lowell Observatory Photographs)

Lowell died in 1916, and for several years there was no further search.

In 1919 Dr. W. H. Pickering, of Harvard Observatory, made a theoretical study of Neptune's orbit (Neptune this time, and not Uranus) and came up with the same conclusions as Lowell: that there was another planet beyond Neptune's orbit. Using this study, the Mount Wilson Observatory took several pictures of the area where Pickering predicted the planet would be found. Once again faint images of Pluto were picked up by the plates, but were unrecognized until after the discovery of the planet was made at Lowell.

At Lowell, meanwhile, the search was carried on by Drs. V. M. and E. C. Slipher and Dr. C. O. Lampland. But it remained for a young astronomer, Dr. Clyde Tombaugh, newly arrived at Lowell, to make the actual discovery.

On February 18, 1930, Tombaugh was using the blink microscope to compare a pair of plates that had been taken some two weeks earlier. Suddenly a faint point of light made a tiny jump. It was moving too slowly to be an asteroid. It could be nothing else but the unknown planet. Tombaugh checked and rechecked and knew he'd finally found what had been sought by the astronomers at Lowell for a quarter-century.

The announcement of the discovery was made, after further checks, on March 13, 1930—and made headlines around the world. The date was the seventy-fifth anniversary of Percival Lowell's birth and the one hundred forty-ninth anniversary of the discovery of Uranus.

After Pluto was discovered, the search went on for other possible planets. By 1943 the work was virtually completed, but World War II intervened and the hunt was stopped. During all those years only one suspected planet was found. Repeated photographs failed to pick it up again. The object, it is now believed, probably was an asteroid.

During the period of this extended search for a tenth

planet, more than ninety million star images were examined, 29,548 galaxies were counted, and nearly 4,000 asteroids were noted—of which some 1,500 had never been seen before.

From the results of this search, it would seem unlikely that there is yet another planet, although the possibility can not be ruled out entirely.

The best evidence is that Pluto is the outpost of the solar system; that it is the stopping place; that except for some far-ranging comets, it is as far as the solar system goes.

If there is a tenth planet, and if it follows the pattern of the other planets, we might expect to find it at the mean distance of 7,200,000,000 miles from the Sun. Its period of revolution about the Sun would be, theoretically, in the neighborhood of 680 years. And it would move slowly—so slowly, perhaps, that it would be difficult, even with a blink microscope, to detect its movement. If there is another one out there, it may already have been seen, but been mistaken for a star.

Ever since its discovery, Pluto's size has been a matter for speculation. Before the planet was discovered, it had been expected that it would be another giant gas planet, smaller than Neptune, naturally, but even so, a great deal larger than the Earth.

But at the time of Pluto's discovery its diameter was estimated at 8,000 miles—another Earth-size planet. In 1949 observations cut its diameter down to 6,400 miles; and finally, in 1950, when the largest telescope in the world—the 200-inch at Palomar—was trained upon it, it was cut down in size again. This time it was reduced to a diameter of 3,600 miles making it just 500 miles in diameter bigger than Mercury.

And this is all right, of course—except for one thing.

For Pluto to have the effect it does upon Uranus, it has to be much more massive than the Earth. To have that

effect, the mass of Pluto has to work out to some ten times the mass of Earth. And unless Pluto is much larger than 3,600 miles in diameter, or is composed of an entirely new kind of matter—a kind we have never dreamed or thought of—it can't be that heavy.

There have been some attempts to explain this situation. None of the explanations, of course, can be proved, for data is lacking.

One idea is that Pluto at one time was hot, and that, as it cooled, it was left with an atmosphere of methane. But at the temperature of 400° below zero, Fahrenheit (which is Pluto's present temperature), the methane atmosphere would be turned to liquid. If Pluto were made up of dark rock, and if this liquid methane were collected into one great ocean—then, ask the supporters of this idea, wouldn't it be reasonable that the brighter ocean would reflect a great deal of light, while the black rock would reflect none at all? And, if this were the case, is it not possible that what the astronomers have measured is the ocean only, and not the planet upon which the ocean rests?

Another idea, very similar, is that what the astronomers are seeing is only the reflection of the Sun, shining back at us from a highly reflective surface. This surface could either be made of ice, or it could be a planetary crust which itself acted as a polished surface. You yourself can get this same effect if you place a polished steel ball bearing against a black background, with a brilliant light shining behind you. It is almost impossible to see the ball itself; all you can see is a brilliant spot reflecting back the light source from the polished surface.

Another possible explanation, of course, is that Pluto really is no more than 3,600 miles in diameter, and that it is as massive, for some reason we can't understand, as it appears to be. Or, there might be another planet out there, much

larger than Pluto, perhaps of such a black color that it is invisible. But that seems quite unlikely.

In 1955 Lowell astronomers determined that Pluto spun upon its axis once in 6.39 of our days. Pluto shows in most telescopes as little more than a spot of light, so it is impossible to determine any of its surface details. What *can* be seen is a slight, but regular, change in brightness. It is speculated that one side of the planet may be darker than the other. Thus, as it revolves upon its axis, it dims with each revolution as the dark part turns toward us.

Pluto's eccentric orbit has also given rise to the speculation that it may be no proper planet at all, but at one time may have been a moon. Had it been subjected, it is argued, to the same processes as the rest of the planetary bodies, at the time the solar system was born, its plane would have been closer to those of the orbits of the other planets.

There is the possibility that it may at one time have been a moon of Neptune, and may somehow have escaped. Scientists can work up a fairly convincing mathematical sequence which explains exactly how such a thing could happen. Which doesn't mean, of course, that it did happen —simply that it could.

And there is yet another possibility which is sometimes mentioned. Could Pluto be a burned-out star, a star with its fires gone out, with nothing left but neutrons stripped of all electrons and packed together so tightly that it is massive beyond all imagination? We know that there are such stars, burned out and collapsed into planet size. They are the ash heap of a star long dead. But if Pluto is such a thing as this, then where could it have come from?

This is outrageously fantastic, of course. There is not a shred of evidence to bear it out. It's just a wild shot in the dark, so much so that at first we weren't going to mention it at all, but it's such a lovely idea we couldn't leave it out.

17.

Comets: Outriders of the Solar System

ONE EVENING IN THE SPRING OF 1910 THE PHONE rang in our home. It was a neighbor, calling to tell us that the comet could be seen. No one asked which comet, for it was Halley's Comet, and it was a name that was on every tongue that spring.

So our family walked out into a field and looked up in the sky, and there the comet was. It was a wispy thing and quite unspectacular and I was disappointed. For I had seen drawings in the newspapers which had represented it as a streak of fire from horizon to horizon.

Halley's Comet, to tell you the solemn truth, was no great shakes back in 1910; but apparently there had been other years when it was worth the looking.

And even wispy as it was, we were lucky people. For

of all the millions who searched the heavens for it, there were few that year who saw Halley's Comet.

I was not quite six years old that spring, and my father said to me: "You may be one of the few people in the world who'll see Halley's Comet twice. It'll come back in seventy-six years and if you live long enough, you can see it then."

This remark brought me and the future squarely face to face for the first time. We went back to the house and I went upstairs to bed; and I lay there, stricken by the realization that some day I'd grow old and eventually I would die. When the comet came again, I'd be an old, old man. More than likely I'd have chin whiskers way down on my chest, just as Grandpa had. Until that day I'd had no thought of time. Time, my time, was something that ran on and on, forever. And while I'd had a vague idea that some day I'd grow up, there had never been a thought that I would grow old as well.

For a long time, however, I lived with a sense of childish glory. Even if I must grow old, I told myself, I still would be one of the few who had ever seen Halley's Comet twice.

But now I'm not sure there is any glory in it, even if it happens. There is, I know, very little chance that I'll see the comet when it comes even if I'm still alive. It was pale in 1910 and it may be pale again in 1986—and it may not come at all. For you cannot count on comets.

Halley's Comet, in particular, is an ancient comet, and it may be wearing out. It may never again flame across the sky as it did in ages past.

With one exception—in 163 B.C.—each visit of Halley's Comet has been recorded since 240 B.C. There is one earlier Chinese record, for 467 B.C., but we can't be sure of it. There is no record for 163 B.C., but there were brilliant comets in 166 and 165 B.C. Whether one of these was Halley's Comet, there is no certainty. The average orbital period of

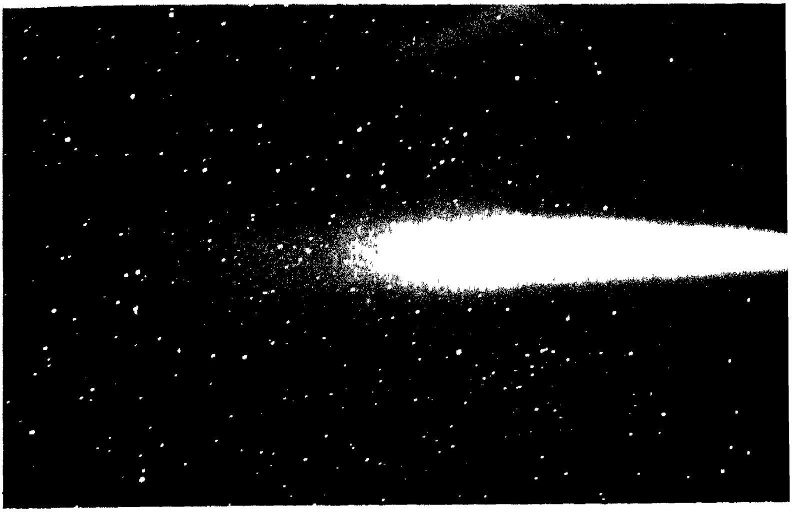
the comet, figured through the years, is seventy-seven years, with a possible two and a half year variation either way. So the 165 B.C. comet, or even the one in 166 B.C., could have been Halley's. In 1145, and again in 1378, the comet was a disappointing sight, as it was in 1910. But in all the other years, if we are to believe the records, Halley's Comet was a brilliant sight which persisted for weeks.

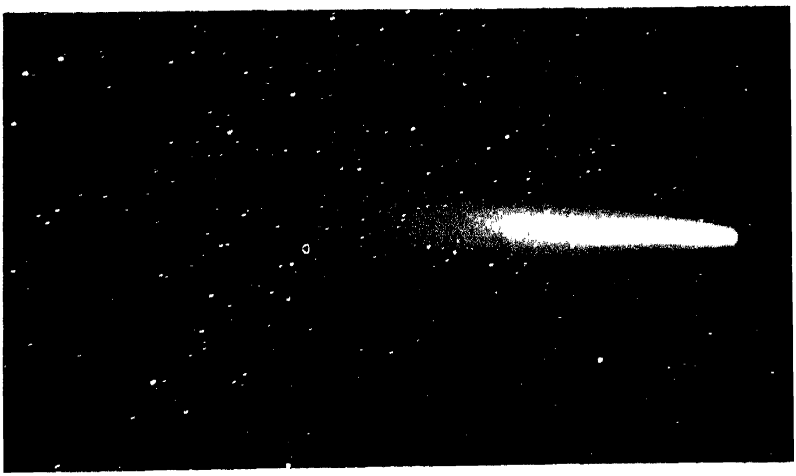
The visit of 1066 came in the year in which William the Conqueror invaded and subdued England. In the Bayeax Tapestry, which commemorates the invasion, the comet is shown in what were bright colors, before the fabric faded. This is, so far as known, the first picture of a comet. The comet must have been particularly showy that year to have warranted inclusion in the tapestry.

Edmond Halley was a British astronomer who, in 1705, published a paper in which he gave the figures he had worked out for the orbits of fourteen bright comets that had been recorded in past ages. Apparently, he was the first man to realize that comets follow orbits and revisit the skies of Earth at regular intervals. Previously, comets had been regarded as wanderers which came out of nowhere and went back into nowhere.

In his paper, Halley suggested that the comets of 1456, 1531, 1607 and 1682 were really the same comet appearing at intervals of seventy-five years. He predicted that it would appear again in 1758 or 1759. Halley died in 1742; but on Christmas night of 1758 his comet was picked up by telescopes as a faint object in the sky. In a few months time it was flaming overhead, visible to the naked eye. Computation proved that it was, as Halley had supposed, the same comet that had been seen time and time again. So it was called Halley's Comet.

In its 1910 visit, Halley's Comet swung in close to the Sun, to a point about halfway inside Mercury's orbit, a mere





Halley's Comet as it appeared in 1910. These photographs were taken in Hawaii. The top picture was taken on May 12, and the bottom one on May 15. (Mount Wilson and Palomar Observatories)

18 million miles from the surface of the Sun. In 1948 it was its farthest from the Sun, out beyond the orbit of Neptune. Now it is coming back again (if nothing has happened to it), gaining speed as it plunges inward toward the center of the solar system.

We've talked a lot about Halley's Comet, which does not mean it is the only comet or that it is the only one which is of any interest. There are thousands of other comets, and many of these others also are of much interest.

Comets are generally members of the solar system, although occasionally there may be an intruder from space outside the solar system.

Comets, so far as we can learn, are largely made of ice. They generally range in size from a diameter of a mile up to a diameter of ten miles. There are a few, however, with diameters of a hundred miles or more. The ice of which a comet is made is largely composed of frozen gases. Out in the absolute cold where the comets roam, gases would freeze solid. Comets may also contain some ordinary water ice; and embedded in the ice are small particles of stone and metal.

As might be supposed, comets are not very massive. Because of this, their orbits can be easily altered by a close approach to a planet.

As a comet nears the Sun, it begins to vaporize. The ice never melts, but, influenced by the heat, becomes gas once again. But the whole body of the comet does not vaporize. Rather, the vaporization seems to occur in layers. As each thin layer disappears, new solid ice is exposed to the heat of the Sun, and another layer vaporizes.

With the vaporization of the gases, tiny particles may be pushed out into space by the pressure of light, to form a comet's tail—although this does not always happen. Approaching the Sun, the tail, if there is one, will trail behind the

comet, outward from the Sun. Going away from the Sun, the trail will stream ahead of the comet, outward from the Sun. It is the direction of the Sun's light pressure, and no other factor, which determines the position of the tail. Comets have been reported with several tails; but these instances are not too common.

In its approach toward the Sun and until it has fled out of range of the Sun's heat, a comet suffers a considerable loss of material. The icy gases boil away into space; the particles which make up the tail are lost; and some of the small chunks of metal and stone encased in the ice drop out along the way. With this regular loss of material, comets disintegrate to some extent on each visit to the inner portion of the solar system. The lifetime of most comets, therefore, cannot extend much beyond several thousand years. At times, it is known, comets have split in two, or even into more than two pieces. In some cases showers of meteorites have been pinpointed as lying in the old orbit of a comet which has disappeared. Whether these swarms of meteorites are the debris of the comet can't be known, of course; but there is a good possibility that they are. The icy gases may have vaporized away, but the metal and stony gravel that was embedded in the ice continues in its orbit.

Many comets, still in the best of shape, still showing up regularly, are associated with meteorite swarms. These swarms travel approximately the same orbit as do the comets, but are not necessarily present at the same time as the comets are in sight.

It is supposed that at one time these various groups of meteorites may have been closely associated with their comets, and may have traveled along closely with them. But as the years went on, the swarms got scattered out, some of them running ahead of their comets, others lagging far behind. It is theorized that the influence of some of the planets may have

distorted the orbits of the meteorites, causing them, so to speak, to fall out of step.

The frozen gases most likely to be found in comets would be methane, ammonia and water. All of these would be frozen in the form of tiny crystals.

Since 1882 there have been no spectacular comets. Most of the comets we have had since then—and there have been a lot of them, of course—have either been rather pallid affairs or comets which could be detected only by a telescope. The old drawings and woodcuts, however, show fiery balls with vast, spreading tails behind, lighting up the countryside or city. In the fifteenth and sixteenth centuries there were a number of bright comets which were seen for weeks at a time.

And in those days, when little was known of science and the most common reaction to any unusual happening was superstitious fear, comets were regarded as messengers of ill omen. They were supposed to forecast floods, plagues, fire, death—and the people dreaded them. This, as we know now, of course, is a lot of foolishness; but to the people of those days a comet was a thing of terror.

During the 1910 return of Halley's Comet, there was a lot of talk about the terrible things which would happen if the Earth should pass through a comet's tail. In 1910, the Earth actually did pass through the comet's tail—and absolutely nothing happened.

For the tail of a comet is made up, mostly, of nothing. It has been estimated that there is less material in 2,000 cubic miles of a comet's tail than there is in a cubic inch of air at ground level on the Earth. The shine of the tail, apparently, is due to the excited state of the particles which go to make it up.

Comets move in elongated orbits, coming in close to the Sun, then going deep into space before they make a short

turn to travel inward toward the Sun again. Some comets move in families. This is due to the fact that from time to time comets come under the influence of certain planets, which changes and shapes the course of their orbits. Jupiter, as the largest planet, has been the most influential in this regard, although other planets have their families of comets as well.

Jupiter has a family of about seventy such comets. They have an orbital period of from five to ten years, going out approximately as far as Jupiter's orbit before turning back again. Eight other comets form a family which goes out beyond Pluto, giving rise to further speculation that there may yet be a planet beyond Pluto's orbit.

And where, you ask, do the comets come from? We have seen that in a few thousand years a comet will use itself up. Thus it is reasonable to suppose that in the billions of years since the solar system was formed all the comets should have long since disappeared. But they are still with us. There is no shortage of them.

E. J. Opik, one of the world's outstanding astronomers, has an answer to this seeming paradox. He suggests that a vast cloud of comets, perhaps as many as a hundred billion, hang about the outskirts of the solar system. Parts of the solar system, but lying at so great a distance that the Sun's gravitation has little effect upon them, they still travel along with us, strangers hanging on to our very fringes.

It must be understood that no matter how feeble the Sun's hold upon them may be, these comets still are in orbit. If this were not the case, they would not retain their places as members of the solar system. But their orbital speed must be fantastically slow as they drift along with the rest of us. Their temperature must be so close to absolute zero that one could scarcely tell the difference—perhaps only a fraction of a degree removed from that state where all atomic motion ceases.

Opik calculates that the farthest of the comets might be out 100,000 times farther from the Sun than is the Earth. This would put them at a distance from the Sun of more than nine trillion miles, somewhat better than a light-year and a half—not quite halfway to the nearest star. The nearest star is Alpha Centauri, at a distance of slightly over four light-years.

So, if we figure the orbits of these farthest comets as the actual rim of the solar system, the system in which we live becomes larger than we thought. If Opik is correct, then we must consider that the solar system continues out to that farthest comet. In such case, the volume of space occupied by the solar system is increased by some ten billion times the space which is inside Pluto's orbit.

Opik believes that the comets were formed at the time the solar system came into being, and that they have remained on the fringes ever since. It is likely, he thinks, that they were formed out of the fragments of the clouds of dust from which the system was born. It is probable, he estimates, that their combined mass would be equal, approximately, to the mass of Earth.

And when we consider such a mass existing in so much emptiness, it is easy to realize that it would be thinly spread. The average distance between any comet and the next, if they were spread out evenly (which they probably are not), would be on the order of 2.7 billion miles, which is the distance between Earth and Neptune.

These far-out comets would not only be subjected to the feeble pull of the Sun, but, under certain circumstances, to the weak pull of other stars as well. Over the course of millions of years, as our system passed by other stars, the orbits of some of these comets may have been disturbed sufficiently to start the comets falling inward toward the center of the solar system. Under some conditions they would then estab-

lish new orbits, but orbits still far out; in other instances they would come under the increased influence of our Sun and of the planets, and would be forced into orbits known as periodic orbits, which would bring them back time and time again toward the center of the solar system.

Or it is just as possible that such disturbances might nudge them entirely out of the solar system, so that they would enter interstellar space. There, after years of wandering, they might attach themselves to some other sun and take up an orbit round it. And there might be a few comets which would flash through the center of the solar system and return again to an orbit in the outer darkness, never to be seen again.

This, then, according to Opik, is where the comets come from. There is a vast reservoir of them in the remote outer reaches of our solar system. It may be that the spectacular displays of the fifteenth and sixteenth centuries were due to a batch of new comets arriving in the center of the system because of some disturbance which had pulled them from their outer orbits, perhaps millions of years before.

In 1953 Raymond A. Lyttleton proposed another theory which might explain the origin of comets. He suggested that they are formed as the Sun passes through the many dust clouds which exist between the stars in our galaxy. As the solar system passes through these clouds, the Sun sweeps up some of the dust and carries it along. Over thousands of years the dust would pull together into small masses as a result of its own gravitational attraction. In this way, Lyttleton believes, the nucleus of a comet might form.

Comets may seem to be fairly remote things; but there is a chance that they may have played a great part in arranging for you and me to be here at all.

Professor J. Oro, of the University of Houston, suggests that comets could have had something to do with the rise of life on Earth. He believes that comets, by colliding with

the Earth, may have provided some of the carbon compounds which went into the making of the amino acids and the other chemical structures necessary to the creation of life forms.

Dr. Urey and others have estimated that in the course of the Earth's long history, some hundred comets have collided with the Earth. This, Oro calculates, would have added 200 million to one trillion tons of comet material to the atmosphere of Earth during the first two billion years of our planet's existence. This is the time during which life must have come about upon the Earth.

There is the possibility, of course, that in the early days of the solar system comets were much more abundant than they are today. In such a case, many more than a hundred may have collided with the Earth, and perhaps most of them in that primeval period. Which would mean, of course, that much more comet material than has been estimated may have been added to Earth's early atmosphere.

We know that somehow, through some circumstance which we do not understand, Earth must have lost its primitive atmosphere. That atmosphere was then replaced by the one which we know today—the sort of atmosphere in which life as we know it is possible.

It was during the time when our new type of atmosphere was building up, it is believed, that life first appeared—in its most simple form, of course.

Oro suggests that it would have been at this very time that the comets, by adding a significant amount of carbon compounds to the Earth, could have made their contribution to the rise of life. He suggests that the comet carbon compounds, mixing with the gases which issued from the rocks of Earth because of volcanic and other processes, formed the early lower atmosphere in which life processes could go forward.

18.

Way Out

WE HAVE COME A LONG WAY SINCE WE STARTED ON this book—out to Pluto and beyond Pluto to the last circling comet trillions of miles from the center of our system.

Some day—and perhaps sooner than we think—man will venture into space. To the Moon first, and from the Moon out to Mars and Venus. And, once we've learned the tricks and techniques, out to the other planets. Eventually man will land on Pluto; and if there should be another planet—a tenth planet —beyond Pluto's orbit, he will land there, too. There are four planets man may never land on. We set out to say he "will" never land on them, then we changed our mind and put in that qualifying "may." For it is never safe to be entirely positive about what man will or will not do. He's an ingenious creature and he's apt to come up with a sneaky trick to accomplish the impossible. So, one day, man may enter the atmospheres of the four giant planets, although at the moment it seems extremely unlikely that he will. But he will land upon their moons.

In time, some hundreds of years from now, perhaps (certainly less than a thousand), man will have explored all of the solar system. He will have visited all the places where it's possible to go and he'll have learned a lot of things about which now he can only speculate. We do not know what we'll find on our planetary neighbors. On some of them, perhaps, nothing of any material value. On others, perhaps, some commodity of a value we cannot now imagine. But one thing we know we'll get, and that is: knowledge. Not only knowledge of the planets, but greater basic knowledge and greater knowledge of the stars and of the universe.

And, just possibly, something that may be of more value than knowledge—the realization that we human beings are a single race, a single family, which should live together in peace and co-operation. For out in space no man will ask another if he is English or Russian or American or Chinese or Bantu. Nationality will become a mere detail in space. Differences in politics and religion and economic viewpoint will vanish. For out in the black cold of space and on the bleak landscape of a planet millions of miles from Earth, these things will not matter. The only thing that will matter will be the common humanity of all men. More than likely, faced with the vastness of the solar system, man will realize that he still is huddled in the "cave" of a single planet, and that he faces an outer world which is bigger and more fearsome and more glorious than the outer Earth must have seemed to primordial man as he huddled in his cave. Man will realize that all this space is his, and that all it contains is his if he can only grasp and hold it. But if he's to do this job, there will be no room for bickering or for fighting on the old home planet. Space may finally do for man what all the efforts of men of good will for many centuries have failed to do: it may make him live at peace on a planet full of neighbors.

For, in all truth, the Earth is the house in which we live, and the solar system, for all its vast distances, is no more than a new front yard into which we are about to venture.

And once we have explored this new front yard of ours and have become familiar with it—as familiar as today we are familiar with the Earth—what will we do about the stupendous reaches of space which extend out into the galaxy? Will we ever be able to take the road to the other stars?

The way to Pluto is long; but the way to the stars is farther. We may measure the way to Pluto as so many miles; but when we're dealing with the stars, the distances become so great that miles are meaningless. So we chalk up the distances in light-years. A light-year is the distance that light travels in a year—5,880,000,000,000 miles.

The star nearest us is Alpha Centauri, a multiple star, composed of two bright stars which you can see (if you live in the southern hemisphere) as one, and a third star so faint that it is invisible to the naked eye. Proxima Centauri, the faint star, is 4.25 light-years distant; the other two stars which make up the system are 4.3 light-years away from us.

The second nearest star is Barnard's Star, six light-years distant; Wolf 359, at a distance of 7.7 light-years from us, is third; Luyten 726.8 is fourth at a distance of 7.9 light-years.

Forty-three stars are within 16 light-years of Earth. There is evidence that at least one of these, 61 Cygni, at a distance of 10.9 light-years from us, has a solar system. The evidence, strong as it is, does not prove conclusively that 61 Cygni does have a solar system. Nor does the lack of similar evidence concerning other stars prove they do not have solar systems.

The 61 Cygni evidence was discovered in 1944 by Dr. K. A. Strand, of Sweden. The star called 61 Cygni is a double star. Two stars revolve about a common center, mak-

ing one complete revolution about one another each 700 years. Both are faint stars. The brighter one is about one-nineteenth as bright as the Sun; the other is somewhat dimmer than that.

Dr. Strand, in observing and measuring the orbits of the two stars about one another, found that the stars were wobbling in their courses. This meant to him that there was a third, unseen body involved with the stars. Since the wobble was slight, he knew that the unseen third body was of small mass. Working out the mathematics of the problem, he came up with the answer that the third body was about fifteen times as massive as Jupiter.

While a body of this mass is a considerable chunk of matter as compared with any of the bodies, other than the Sun, in our solar system, it is still too small to be a star. A star as small as that never would have formed. So, reasoned Strand, it must be a planet. While a single planet of this sort does technically qualify as a solar system, its existence does not necessarily mean that there are other planets in that system. But, in all honesty and by all rights, one might be excused if one assumed there were. Perhaps a situation could exist where two stars and only one planet were born out of a cloud of dust and gas; but the chances probably would be very much against it.

So far as a planet with fifteen times the mass of Jupiter is concerned, man would scarcely be interested in it except for study purposes. It would be something that he'd want to observe, but probably from a long way off. For it most certainly would have a high gravity and a high escape velocity, and any ship that landed on it might have a hard time getting off.

Some evidence also has been found that another star, 70 Ophiuchi, also has an unseen companion, this one twelve times as massive as Jupiter. But we need not worry about

getting to it in the next few centuries: 70 Ophiuchi is 20,000 light-years from us.

The fact that no other nearby star except 61 Cygni gives evidence of having a planet does not rule out the possibility that other nearby stars may have them. An Earth-size planet —even another Jupiter—would have such a small effect upon the motion of a star that it would not be noticeable. And at the moment there is no way to detect the existence of a planet except by its effects on its star. Planets have no light of their own and the little light they reflect from their sun cannot be picked up by a telescope.

But even if there are other solar systems (and the chances are excellent that there are), what are our chances of ever reaching them?

At the moment they don't seem too good. The stars are just too far away.

But, you might say, suppose we could develop a space-drive that, once out in space, would continue to push us faster and faster, building up our speed to fantastic proportions; could we not get to the stars in a reasonable length of time.

All that is well and good. It conceivably would be possible, except for one thing: Einstein's theory of relativity.

This theory says that nothing—absolutely nothing—except light itself can go as fast as the speed of light. The theory says that, theoretically, at the speed of light mass would become infinite and length would be canceled out. In other words, as a spaceship neared the speed of light it would become more and more massive and shorter and shorter. At the speed of light, which, according to the theory, it could never reach, it would become so massive that it could not add to its mass and it would have no length at all.

If Einstein's theory is correct, and there is evidence it is, then there is a definite limit to how fast anything can go.

Say, however, just for the fun of it, that we could reach the speed of light. At that speed it would take more than four years to reach the nearest star. It would take eleven years to reach 61 Cygni, where there is some evidence of the existence of a solar system. Even this supposes that once we'd left the Earth we could instantaneously attain the speed of light, and could maintain the speed of light, with no preliminary braking of our speed, until we reached our destination. In other words, schedules of four years and eleven years would allow us no time to build up our speed after leaving Earth and no time to decrease our speed preparatory to landing at the end of our journey. And once we had reached our destination, it would take us just as long to get back home again. A man could use up a good part of his lifetime just going to and returning from some of our nearest stars.

But there is a way, perhaps, that we can get around Einstein's theory. There may be something in the theory itself that will help us do it.

There are more and more people in the scientific world who are beginning to believe that there may be a third effect found in traveling at speeds close to that of light. The effect is called time dilation.

What it means is this: That the faster you go, the slower time will run. With increasing speed, mass increases, length is shortened, and time is slowed. At just ordinary speeds, as we think of them today—up to several thousand miles an hour—the effect would be so slight that it would be unimportant. But if we could build up speeds approaching that of light, the effect, if it actually exists, would become important.

If our spaceship, say, were traveling at 90 percent of the speed of light, twenty-five years back on Earth would be only ten years for the people in the ship. Those in the

ship would not notice this, of course. Their ten years would seem like ten years to them. It actually would *be* ten years to them. Clocks would slow down, bodily processes would slow down. Even the atoms of which the ship was composed would move at a slower rate.

At 99 percent of the speed of light, ten years back on Earth would be only one year in the ship.

So, if this should be true—if time does shorten with speed—we could get to 61 Cygni in something like a year if we could travel at 99 percent of the speed of light. We could turn around and come back to Earth again and that would be another year. When we landed on the Earth, we'd be only two years older than we were when we set out. But all our family and friends would be almost twenty-two years older.

And if we could push our ship up to 99.99 percent of the speed of light, the ratio would be a thousand years on Earth to fourteen years on the ship. With such a speed we could journey comfortably and conveniently to stars hundreds of light-years distant. But when we came home again the Earth probably would be so changed we would not recognize it. We'd be strangers coming back to a world that might have long since forgotten us.

But even if the theory of time dilation should prove to be correct, it would solve only a part of the problem. It would mean that travelers to the stars could get there and back in what to them seemed an incredibly short time. But the time on Earth still would be no shorter. The people who waited back on Earth would wait just as long for the travelers' return as if there were no such thing as time dilation.

In another thousand years, perhaps in a much shorter time than that, men will be thinking of going to the stars. In a thousand years, and at the rate our science and technology is progressing, an awful lot can happen. Man is a

clever being. He is clever now; he will be more clever, and maybe even wiser, a thousand years from now. He'll have more knowledge and he will have improved his techniques. He'll know a lot of things, and be able to do a lot of things, that we can't imagine now. He may even break the jinx of the limitation of the speed of light. He may find a way around it; he may dream up a way to duck it. At the moment there is no hint of how it might be done. But give man a thousand years and anything can happen.

And should we be able to go to the stars, then all of creation will be spread out before us. Our new front yard of the solar system, however big it seems at the present moment, will then be a tiny thing.

There are, we're pretty sure, other solar systems waiting out there for us. On some of these solar systems, there are "people" waiting, too.

And along the way we'll gather knowledge, and perhaps a greater wisdom; and, in some final day, a greater understanding of what the universe may be and why we are living in it.

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